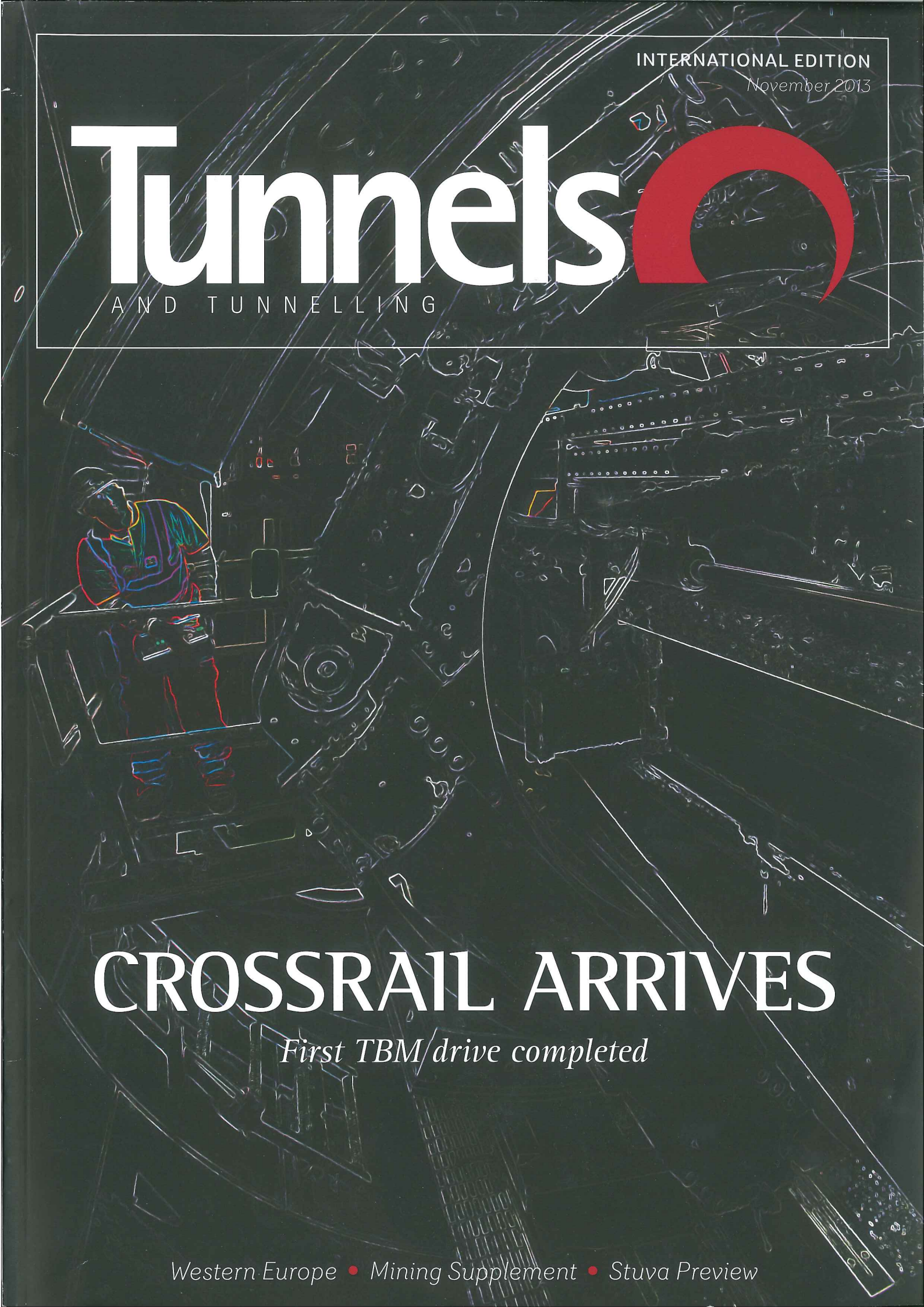
INTERNATIONAL EDITION
November 2013

Tunnels AND TUNNELLING



CROSSRAIL ARRIVES

First TBM drive completed

Western Europe • Mining Supplement • Stuva Preview

SHUTDOWN SHOWDOWN

"DUE TO a lapse in funding, the US Federal Government has shut down." The Senate and the House of Representatives were unable to pass a bill to fund the government before October 1, when the new fiscal year started. Or more specifically, a group of 'Tea Party' Republicans shut down the federal government in attempt to defund the Affordable Care Act, sometimes named Obamacare by detractors.

The world is getting a full view of congress' usual petty posturing, but in this instance the hissy fit concerns what is generally considered a human right in most other countries: affordable access to health care.

It doesn't take hard numbers to show most US citizens support the Affordable Care Act. The bill passed in both the Senate and the House in 2009, and President Obama signed it into law in 2010. The US Supreme Court upheld the Act in summer 2012, deeming it constitutional. And that's not to mention in November 2012, the US reelected the president for a second term, despite the fact that he spent most of his first term working on the policy.

Obamacare has several components, some of which have already begun over the last three years, but one very large thorn in the side of Republicans is the mandate starting in January 2014 for companies with more than 50 employees to offer health insurance or face fines.

Republicans claim they are concerned about the effect on the economy, the destruction of jobs and the financial burden on employers. Though statistics released by the White House show that most US businesses are exempt from the mandate. Specifically, 96 per cent of US companies have fewer than 50 people, and will not have any employer responsibility requirements. Most firms, 96 per cent, with 50 or more employees already offer health insurance.

This means, less than 0.2 per cent of all US companies (about 10,000 out of 6M) may face employer responsibility requirements. As of October 1, despite the shutdown, a few health care exchanges opened for individuals and small businesses to find affordable health insurance.

What these elected officials are overlooking is that removing the barriers to affordable health care opens the opportunity for more entrepreneurship, and therefore greater innovation. And potentially more jobs, more manufacturing and more growth for the economy. It's shocking since pulling oneself up by the bootstraps is a mainstay of Republican hyperbole.

Instead, these Republicans shut down the government the same day the new healthcare website received 4.7 million unique visitors in its first 24 hours, according to the Health and Human Services Department.

While they've likely applauded each other's efforts on staying strong in the face of their party, now, to the rest of the world, the US simply looks weak, and that is a legitimate concern. But surely the nation didn't look very strong with millions of sick Americans unable to receive basic health care

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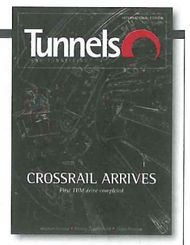
What do you think? Send your views to the editor and join the debate

Nicole Robinson
Americas Editor

Cover
Tunnel completes on the first Crossrail drive as one of six Herrenknecht TBMs arrives in Farringdon



Next issue
In the next issue of *Tunnels* we look into the flagship of mechanised tunnelling, the tunnel boring machine with a look to hybrid machines from leading TBM manufacturer Robbins, and a paper on the validation of TBM advance rate predictions

This month...

10 YEARS AGO

The first Channel Tunnel Rail Link (CTRL) TBM drive has been completed in the UK. The 8.15m diameter machine boring contract 320, one of the more critical sections of the 39km-long section two, was the first to complete. The Hochtief/Murphy joint venture won awards and shaved 50 days off the scheduled time on the USD 236M contract. For the first time in the UK, glass fibre bars were used instead of steel reinforcement for the diaphragm headwalls, easing the burden on disc cutters and winning recognition at the Tunnelling Awards presented by the BTS and *Tunnels*.
Tunnels and Tunnelling, November 2003, p.7

20 YEARS AGO

The Anglo-Arab Cairo Wastewater Consortium (CWC) has triumphed once again, winning the latest tranche of tunnelling work, worth USD 136.3M on the Egyptian capital's massive sewerage expansion scheme, the Greater Cairo Wastewater Project. CWC, a JV led by Tarmac alongside Balfour Beatty, Cementation, Edmund Nuttall and The Arab Contractors/Osman Ahmed Osman & Co, beat off fierce competition from seven other bidders. Tunnelling will comprise 11km of branch sewer tunnels and 46 shafts. Shaft diameters vary between 4.8 and 6m. Tunnel diameters are of two sizes: 2.3m od and 2.6m od. CWC already has one Lovat TBM in storage but intends to buy another machine for the project.
Tunnels and Tunnelling, November 1993, p.7

Above, left: The Second Coen Tunnel immersed crossing, p.22

Above, middle: Mining in Australia has impacted more than the land, p.33

Above, right: Mine development benefits from mechanisation, p.54

Contributors

Adrian Greeman
Adrian is a former editor of *Tunnels* and a longstanding regular contributor.
A freelance technical journalist, he produces articles for a range of subjects, and has written for a number of leading engineering titles. In this issue of *Tunnels*, Adrian travels to Australia to cover local mining operations, developments and the culture surrounding tunnelling's sister industry.

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LTA imposes financial penalties for operational incidents

Singapore The Land Transport Authority (LTA) announced its intention this week to impose financial penalties on one of its metro operators. Some SGD 860,000 (USD 690,000) will be levied on SMRT Corporation for separate incidents on the North-South and East-West Lines, the Circle Line.

The reasons given in an LTA report included SMRT lapses during a trackside fire at Newton Station, rail defects on the Circle Line and two faults of train movement. The maximum fine a public transport operator can face is SGD 1M (USD 800,000) per incident.

The total financial gains from the penalty fees will be donated to the Public Transport Fund to "help needy families with fares".

Chew Hock Yong, LTA chief executive said "LTA takes a serious view of these breaches... that disrupt the operations of the rail system. In particular, lapses on the part of operators which may potentially lead to safety implications... and we expect the operators to review and improve their processes to prevent future occurrences.

BRENNER MAJOR TENDERS

Austria/Italy The Brenner Base Tunnel client, BBT, announced two mammoth tenders on 30 September. The total value was EUR 830M, with EUR 460M for the Tulfes-Pfons contract and EUR 370M for the Isarco River underpass.

The Tulfes-Pfons section requires construction of a total of 38km for: exploratory tunnel extension, a rescue tunnel for the Innsbruck bypass and two connecting tunnels. The exploratory tunnel will continue 15km southwards from Ahrental into the Pfons Municipality and is the first use of a TBM on the Austrian portion of Brenner.

The rescue tunnel will be 9.1km. All excavation and lining of the rescue and connecting tunnels is included in the contract. Work will begin in summer 2014 and last five years. The award will go to the lowest bidder.

The Isarco tender covers construction of the main tunnels north of Fortezza and the two connecting tunnels between Oberau and Mittewald that will link to the existing line. The tunnels run only a few metres below the riverbed.

A BBT spokesman said, "Before work on these tunnels begins, a series of preparatory works must be carried out on the surface. For example, the state road SS12 will be moved, two bridges will be built over the Isarco and the Rio Bianco and a loading area will be built adjacent to the A22 highway, which will be needed for the transportation and supply of building materials.

"Roughly 3.5 km of tunnel will be excavated using blasting. A further 1.5 km of tunnel near the Isarco will be constructed using the cut-and-cover method. While this construction work is ongoing, the river flow will be temporarily redirected. The existing railway line will be permanently re-routed."

The contract will be awarded to the tender with the highest overall score, and suggestions for improvements will be heard. Preparatory works should begin in spring 2014, main tunnel construction to begin in summer 2015 and work will last nine to ten years.

Emergency tunnel gets green light at Lake Mead

USA A unanimous vote by the Southern Nevada Water Authority (SNWA) board last month approved a new emergency tunnelling project at Lake Mead in Las Vegas, Nevada.

Projections for the lake's water levels indicate one of the two existing intakes could soon become inoperable. The emergency tunnelling work would extend the life of Intake 1, the older and shallower of the two. The SNWA deemed the work an 'emergency' to fast track the project, which requires Intake 1 to be temporarily capped and drained. SNWA stated the best time to complete the work is in the winter months when water demand is lower, requiring an immediate start or delay to next year.

Worth USD 12M, the work will be a change order to an existing contract with Renda Pacific, which excavated 2,820ft worth of tunnels to eventually connect the forthcoming third intake, with Intake 2. New construction includes a 110ft vertical shaft from the bottom of the pump station at Intake 1 to the connector tunnels for Intakes 2 and 3.

Tunnelling for the construction of Intake 3 is still underway, having realigned the starter tunnel after flood events slowed progress.

The project was originally scheduled to complete in 2014. The SNWA is not certain this will be accomplished.

Intake 1 could be inoperable should the water levels at Lake Mead drop another 40ft, or below 1,065ft when water quality would be affected, according to SNWA. The US Bureau of Reclamation (BOR) reported the lake could drop another 30ft by 2015.

News briefs

GREAT BRITAIN

Work to repair to Dingle Station tunnel began last month in Liverpool, local media reported. SES Contracting has been awarded a contract to undertake a tunnel lining condition survey and tunnel remediation and stabilisation works. Planned completion of the tunnel remediation works in the vicinity of the collapse area during December. The disused railway tunnel collapsed on 24 July 2012, resulting in 11 houses being declared "unsafe for the forseeable future". A previous survey of the 1.2km tunnel by the Liverpool City Council could not determine the cause of the collapse. The section of the tunnel that collapsed was being used as a garage

BRAZIL

A man has been arrested on tracks in Bochum, Germany, following driving his car through an underground train tunnel while intoxicated, news reports revealed late last month. The 27-year-old man was found to be more than three times over the legal limit for alcohol allowed while driving. He reportedly had not intended to take the underground route.

GREAT BRITAIN

German engineering firm Siemens has introduced the Inspiro concept, which could be built in Britain if the Mayor of London placed an order for the new trains. The trains are fully air conditioned and a lot more spacious than the current models on the London Underground.

CLEM7 SALE AGREEMENT SIGNED

Australia Brisbane's Clem7 tunnel has been sold. Queensland Motorways has signed a "definitive agreement" to acquire the tunnel from receivers for AUD 618M (USD 583M), less than a quarter of its construction cost of AUD 3bn (USD 2.8bn). The deal represented the current value, rather than construction costs, and should be finalised over the next few months, reported local media.

Queensland Motorways already owns both the Gateway and Logan Motorway toll roads in the region. CLEM7 toll revenue will represent just over 10 per cent of total Queensland Motorways toll revenue.

The original operator of the tunnel, RiverCity Motorways, entered receivership in February 2011. It owed approximately AUD 1.2bn as toll collections were below forecasts. KordaMentha partners Martin Madden and David Merryweather were appointed as the receivers and managers to RiverCity Motorways. KordaMentha has successfully worked as a receiver for other complex infrastructure projects, including the Lane Cove Tunnel and the Cross City Tunnel, both in Sydney, Australia.

Madden said in 2011, "We will need to work closely with the management team and the Brisbane City Council to secure a long term sustainable business for what is a valuable asset in Brisbane's road network. Operationally, Clem7 is performing well and we do not intend to make any major operational changes."

Atkins scoops Riyadh work

Saudi Arabia Atkins was awarded a GBP 75M (USD 120M) lead design contract for three of the six lines of the Riyadh Metro. Atkins announced that the company would lead a design joint venture with Spanish consultancy Typsa – the FAST consortium of FCC, Samsung, Alstom, Strukton and Freyssinet. The JV was made responsible for lines four, five and six.

The spokesman added, "FAST's design and build package, awarded by the Arriyadh Development Authority includes 25 stations, two depots and seven park and ride car parks, with a total capital cost of approximately GBP 5bn (USD 8bn).

Uwe Krueger, Atkins CEO said, "Riyadh Metro is a landmark project which will raise standards of living and support long term sustainable development throughout the city, acting as a catalyst for further investment in all aspects of the public realm and built environment.

"We are one of the few organisations in the world with the breadth and depth of technical expertise and regional market experience to deliver a project of such scale and complexity. Our track record on other major metro programmes in the region, as well as our work on projects such as King Abdulaziz International Airport in Jeddah and the London 2012 Olympic and Paralympic Games, was a key factor in our appointment."

Compensation scheme for listed workers

Great Britain Eight major construction companies announced a scheme to compensate workers whose names were on The Consulting Association (TCA) database. The practice of listing workers, and thus negatively affecting their reputations, is known colloquially as 'blacklisting' in the UK. The debate surrounding the TCA has been prominent in the last year.

The new scheme, The Construction Workers Compensation Scheme, should make it as simple as possible for "any worker with a legitimate claim to access compensation", the companies announced in joint statements.

The eight companies: Balfour Beatty, Carillion, Costain, Kier, Laing O'Rourke, Sir Robert McAlpine, Skanska UK and Vinci, all apologised in the statements for their involvement with TCA and the impact that its database may have had on any individual construction worker.

The companies' statement added, "Worker representatives have been invited to enter into a period of engagement to ensure that the proposed terms of the scheme are fair and attentive... The companies involved in the scheme would support the introduction of a code of conduct to ensure nothing like this can happen within the construction industry again."

The statements noted that TCA was closed in 2009, and a large number of construction companies were subscribers to, or users of the database.

Northwest Washington tunnel approved

USA The DC Water Board of Directors has approved the construction contract to build the First Street Tunnel, a medium-term measure to address localised flooding.

Skanska/Jay Dee Joint Venture was selected based on technical score

and cost proposal, DC Water stated. The USD 157M bid is for design-build, allowing for more contractor innovation and greater coordination with the contract owner. Design-build teams also assume a portion of the design responsibility.

This project consists of a 19ft (5.8m)-diameter tunnel slated for completion in 2016. The tunnel will store eight million gallons of stormwater, capturing it before it can make its way to the combined sewer system. The stormwater will be stored in the tunnel during rainstorms and pumped into the sewer system once the storms subside.

Allen Lew, chairman of the DC Water board of directors and co-chair of the Mayor's Task Force, said: "This is a significant component to the medium-term relief from flooding in these neighbourhoods. We specifically went with a design-build contract to increase flexibility and to save time in order to meet our Task Force timelines."

Bangalore Metro gets new target date

India The new target completion date for the Namma Metro, also known as Bangalore Metro Phase 1 project may be extended to 2015, as work on the underground stretch will take longer than expected local news reports revealed last month. The underground stretch is expected to take 12 months for track laying to be complete. Tunnelling work has started, while the TBM, Margarita, recently completed tunnelling up to Minsk Square. Tunnelling of the remaining 220m is taking place near City Railway station. The first deadline of 42.3km of Phase 1 was June 2013. It was then pushed to June 2014, then December 2014. The deadline now stands at March 2015.

Project spokesmen have announced that delays will not impact Phase II.

FORTALEZA GETS CUP INVESTMENT

Brazil An Acciona-led JV won a BRL 2.3bn (USD 1bn) contract to build a metro line in Fortaleza with Cotenco Engenharia. The new 12.4km line will reach 12 stations and carry 400,000 people a day. The consortium that also features Brazilian engineering firm Cetenco Engenharia will install four TBMs which the local state government acquired itself for construction of the line.

The tender for the completion of civil works for the 'Linha call Leste' (East Line) underground transport system was awarded to the consortium for presenting the lowest bid. The contract requires the construction of 12 new metro stations on a 12.4km alignment, with connections to the existing Western Line and South Line.

The work forms part of the Great Cities Mobility Scheme launched by the Brazilian government to develop transport infrastructure in the major cities that have been selected to host the Fifa World Cup in 2014.

An Acciona spokesman added, "Fortaleza, the capital of Ceará, has a population of 3.6m and is an important tourist destination in the northeast of Brazil. The city's new metro line forms part of the Federal Government's plan to improve urban mobility. As a result, Fortaleza's new metro line will be partly financed with federal government funds."

Indianapolis awards Lower Pogues Run design

USA Citizens Energy Group selected Parsons Brinckerhoff to design the Lower Pogues Run CSO tunnel in downtown Indianapolis, Indiana.

Lower Pogues Run is one of five major components of a 25-mile, deep-rock storage tunnel system to capture and convey CSO for treatment at the Southport wastewater treatment plant in Indianapolis.

The project includes approximately two-miles of 18ft finished diameter deep-rock tunnel that will receive flows from six existing primary CSO outfall structures in downtown Indianapolis.

Parsons Brinckerhoff is responsible for preparation of an advanced facility plan and detailed design of the tunnel project. The advanced facility plan report is expected to be completed by the end of 2013. Detailed design is scheduled for completion by the end of 2015 with construction slated for completion in 2021.

Victims found following hydropower flood

Vietnam The bodies of two workers swept away by unexpected flooding in a hydropower tunnel were found yesterday, local media reported. On 26 September three workers were engulfed and swept away by rising floodwater while working a night shift in a 4m-diameter headrace tunnel at the 18MW La Hieng plant.

Phu Yen Province in central Vietnam mobilised 60 soldiers with divers and boats to search for the missing workers along with seven 600cu.m per hour pumping machines working at full capacity. The rescue operation had been suspended for a week due to flooding of the tunnel gates.

Some 1.7km of the excavation was complete at the time of the tragedy, of a 3.5km total.

Eglinton launches second TBM

Canada The second TBMs mining the Eglinton Crosstown LRT project in Toronto launched in mid September while the first machine, which launched in June, stopped for trailing gear installation.

The first two machines will mine eastward from Black Creek Drive. A second pair of TBMs will dig from just west of Leslie Street heading west toward Yonge and Eglinton. The machines will bore a little more than 10km of LRT tunnel at a rate of approximately 10m to 15m a day.

The new LRT line will run about 19km along Eglinton Avenue and will include up to 25 stations. More than 10km, from approximately Keele Street to Laird Avenue, will be underground. The Eglinton Crosstown LRT is expected to be in service by 2020 and will create thousands of jobs.

"Our government is moving forward with the largest transit investment in a generation to get the region moving.

"The new Eglinton Crosstown LRT line will get commuters to work, school and play faster than ever before -- up to 60 per cent faster than today," said Glen Murray, Minister of Transportation and Minister of Infrastructure.

Delhi Metro ITO breakthrough

India Delhi Metro Rail Corporation announced the second and final breakthrough at the ITO metro station yesterday. Tunnelling work has now been completed for the Delhi Metro Phase Three's Central Secretariat to ITO section.

The tunnel drive was 700m at a 5.7m finished diameter. The parallel 678m tube broke through on 18 September. Maximum depth was 18m where the alignment passed below Tilak Bridge. The EPBM was manufactured by Shanghai Metro Shield Corporation. Segments were cast at the Mundka Casting Yard.

Excavation starts for Ottawa LRT

Canada The first blast for tunnelling on the City of Ottawa's downtown light rail tunnel took place on September 16, while roadheader assembly had already started in the middle of last month.

Rideau Transit Group won the CAD 2.1bn (USD 2.13bn) contract for the 12.5km east-west Confederation Line, which includes a 2.5km tunnel to be completed by 2017.

Eventually, three roadheaders will be used for the project; one in each point of access for mining the underground tunnel and station caverns.

The route is expected to be in service by May 2018. The Rideau Transit Group bid is led by a builder, ACS Infrastructure and includes Quebec engineering firm SNC-Lavalin and assorted subsidiaries playing roles as financiers, engineers, operators and maintenance overseers. The consortium also includes Ottawa firm bbb architects.

Rennes Metro contract awarded

France A consortium led by Dodin Campenon Bernard (Vinci Construction) and including GTM Ouest and Botte Fondations, both subsidiaries of Vinci Construction France, as well as Spie Batignolles TPCI, Spie Fondations and Legendre Génie Civil, has been awarded the contract to execute the underground works for Line B of the Rennes metro in France.

The contract, worth almost EUR 320M (USD 431M), includes construction of 8km of tunnel, nine stations and four associated emergency shafts.

The TBM will start up at the end of 2014; delivery is scheduled for February 2018. Some 500 people will work on the site.

SHALLOW TUNNELS OPTION PREFERRED IN MINNEAPOLIS

USA Project designers recommend two shallow tunnels for Minneapolis[1] Southwest LRT line, Metropolitan Council announced October 1, stating it is the most cost-effective solution and best long-term investment for the region.

The project's new cost estimate is USD 1.56bn, up from the earlier USD 1.25bn estimate that did not include any cost to address the location of freight rail in the corridor. In 2011, the Federal Transit Administration directed the Metropolitan Council to study options to keep freight rail in the LRT route through the Kenilworth neighborhood of Minneapolis in addition to studying how to reroute freight trains to St. Louis Park, adding the cost of dealing with freight rail to the LRT project.

"This really became two projects in one: build a light rail line and include the cost of any freight rail adjustments," said Mark Fuhrmann, who leads LRT project development for the Metropolitan Council. "With the recommendation to put light rail in shallow tunnels, no homes or businesses will be acquired, and the Kenilworth Trail will stay within the corridor and be preserved for the long term."

Had staff recommended relocating freight trains to St. Louis Park, tunnels would not be needed for light rail in Kenilworth because there would be enough space to build LRT tracks at ground level.

[3]But that would mean 220-plus LRT trains operating daily through Kenilworth, a significant visual impact that is largely avoided with shallow tunnels,' Fuhrmann said. "It is 20 seconds per train that light rail trains would be aboveground between the two tunnels." A Council planning committee voted down a deep bore tunnel alternative for the corridor in early September.

The line will operate from downtown Minneapolis through the southwestern suburban cities of St. Louis Park, Hopkins, Minnetonka, and Eden Prairie, passing in close proximity to the City of Edina. The proposed alignment is primarily at-grade and includes 17 new stations and approximately 15.8-miles of double track.

If approved by the Council, project staffers plan to submit LRT plans in mid-October to the five cities and Hennepin County for municipal consent by late 2013. Design engineering is scheduled to finish in 2014 with initial construction beginning in 2015.

London's Bank Station plans out for consultation

Great Britain Transport for London (TfL) put the Bank Upgrade plans out for public consultation this week. The consultation will run until 8 November at tfl.gov.uk/bank.

A TfL spokesman said, "The Bank and Monument station complex, located in the heart of the City of London's financial district, is the fourth busiest interchange station on the Underground network with 98 million customers using the station in 2012/13.

"The upgrade of the station is set to be delivered in 2021 following the funding settlement agreed by the Mayor with government in the summer which, although challenging and requiring efficiencies to be found, has protected core investment in London's transport infrastructure over the coming years."

An exhibition will take place at St Mary Abchurch in London from 8 to 11 October, where a 3D model will be on display, along with animated films from the architect.

TfL awarded the contract for the Bank Station upgrade to Dragados earlier this year, in July.

TBM launches on Lilac metro project

Brazil A 10.58m diameter TBM has begun excavation on Line Five - Lilac of the Sao Paulo Metro, local government sources announced last month.

The Herrenknecht machine had previously been employed on the city's Line Four – Yellow where it operated with a cutting diameter of 9.41m.

The 4.8km drive will include six stations and forms part of a USD 29.9bn metro investment by the state government.

Fort Wayne proposes deep rock CSO tunnel

USA The City of Fort Wayne, Indiana, has proposed a seven-mile long, deep rock sewer tunnel to deal CSO overflows, in accordance with its consent decree with the EPA. Local media report the Three Rivers Protection & Overflow Reduction Tunnel would be 12ft (3m) in diameter.

The City of Fort Wayne has hired Black & Veatch for geotechnical data reporting work, and TesTech, for additional geotechnical investigations in phase 1.

Rantaväylä tunnel agreement signed

Finland Lemminkäinen has signed an agreement for the implementation phase of the alliance contract for the Rantaväylä tunnel in Tampere, the company announced earlier this month.

The implementation of the EUR 180.3M (USD 243.2M) project will be carried out by a consortium formed by Lemminkäinen, A-Insinöörit Suunnittelu Oy and Saanio & Riekkola Oy.

The project customer is the City of Tampere, which has authorised the Finnish Transport Agency to act as its representative for the duration of the project.

The work is expected to begin this month and is scheduled for completion by the end of 2017. In addition to the construction of the 2.3km tunnel, the project includes graded interchanges in Santalahti and Naistenlahti along with the related road arrangements.

The construction of the Rantaväylä tunnel between Santalahti and Naistenlahti will contribute to the development of the Tampere city centre and improve the traffic on Highway 12.

The contract will be executed under the alliance model, which is based on a joint agreement between the customer, the contractor and the designers on the project's target costs, other key objectives and risk allocation.

"By working as a team comprised of the customer, designer and constructor, we were able to achieve substantial cost savings through the development of innovative design solutions and work plans." said Harri Kailasalo, executive vice president for infrastructure construction at Lemminkäinen.

What do you think? Send your views to the editor and join the debate

editor@tunnelsonline.info

Atkins creates first UK HSR chair and plans high end test track bed

Great Britain Consultant Atkins has appointed Peter Woodward as its first chairman of high-speed rail engineering for the UK. Woodward is a professor of railway geotechnical engineering and head of the Institute for Infrastructure and Environment at the Heriot-Watt University in the UK.

Douglas McCormick, managing director of Atkins' rail business segment said: "The requirement for high speed rail is growing at pace - with projects worldwide expected to be worth in the USD 100s of billions in just the next 15 years.

The combined efforts of Atkins and Peter Woodward offer a real opportunity to develop solutions in the UK that will overcome global challenges.

"As we also face an ongoing skills shortage in our sector I believe that, together, we have a great opportunity to develop students and produce world-class engineers who can solve the problems of tomorrow.

"High and ultra-speed railways are our future, they have the capacity to transform the economic prosperity of nations and our challenge is to develop the technology to underpin their successful implementation and cost effectiveness across the world.

"Heriot-Watt already has the UK's biggest purpose-built laboratory test track bed (known as GRAFT II) which can predict the effects of high speed trains and simulate the effects of decades of operation on major lines.

"With the support of Atkins we plan to construct the world's most advanced railway test track facility (GRAFT III) and to develop the world's premier railway testing organisation for high-speed."

New chairman of HS2 project announced

Great Britain Doug Oakervee, chairman of High Speed Two (HS2), the planned high speed rail line in the UK, has announced today that he will be standing down at the end of the year.

Oakervee's successor has been announced as current Network Rail chief executive Sir David Higgins, who will join HS2 on 1 January 2014 on a part-time basis before taking up the post full-time from March 2014.

Doug Oakervee, a distinguished civil engineer and former chairman of Crossrail, took up the post of HS2 chairman in April last year. Oakervee has overseen the development of the detailed proposals for the new HS2 line and laid a foundation for the delivery of the rail project.

Patrick McLoughlin, secretary of State for Transport, said: "The fantastic work that Doug Oakervee has delivered as chairman of HS2 is testament to the experience and expertise that he brought to this role.

Oakervee said: "I believe HS2 is vital to the growth of the UK economy and will deliver the capacity our rail network sorely needs."

Keller acquired Esorfranski geotechnical

South Africa International ground engineering company, Keller, has announced that it has agreed to purchase the geotechnical division of the Johannesburg-listed civil engineering and construction company, Esorfranki, for an initial consideration of GBP 31M (USD 49.4M).

Esorfranki Geotechnical is the largest ground engineering business in South Africa, offering design and build services to the mining, civil engineering and construction industries.

In addition to adding a market-leading business run by an experienced management team who will remain with the business, the acquisition will accelerate Keller's entry into selected sub-Saharan construction markets. The business will form part of the Group's EMEA division, Keller announced.

The total consideration, to be paid in cash from Keller's existing facilities, will comprise an initial payment of GBP 31M (USD 49.4M), on a debt and cash free basis, together with a maximum deferred consideration of GBP 9.4M (USD 14.9M) dependent on the achievement of a certain level of profits over the three years following the acquisition.

Completion is expected by the end of November 2013 and is subject to approval by shareholders of Esorfranki at its general meeting on 18 November 2013 and the approval of the South African Reserve Bank.

Laing O'Rourke reshuffle

Australia International engineering and construction group, Laing O'Rourke, has announced that David Savage has stepped down as chief executive officer of its Australian business, and as a member of the Group Executive Committee, with immediate effect.

In light of recent articles in the Australian media relating to business practices at Leighton Holdings, Savage has stepped down to enable him to deal with the allegations made against Leighton during his tenure as a senior executive there. Laing O'Rourke Group Chief Executive, Anna Stewart, commented: "I am grateful to David for taking the tough decision to step down at this time. His action respects the business values and ethical practices that Laing O'Rourke maintains through its relationships."

Central bank rates

	Rate (%)
AUD	2.50
BRL	9.50
CAD	1.00
CHF	0.25
CNY	6.00
EUR	0.75
GBP	0.50
INR	7.50
JPY	0.10
NZD	2.50
USD	0.25

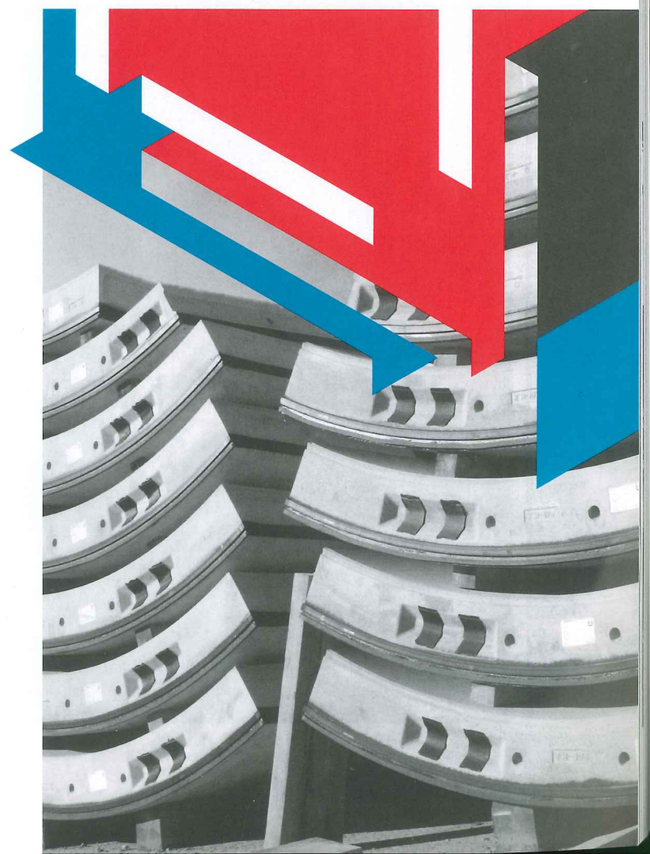
Rates are taken on the 12th of each month.

Oil price

109.3 August 2013

113.1 September 2013

Values are taken on 12th of each month.



CROSSRAIL BREAKTHROUGH

The first Crossrail TBM has finished tunnelling in London. Crossrail announced yesterday that TBM Phyllis had reached Farringdon, the central station, ending its drive from Royal Oak, the western portal. The machine launched 17 months ago by the Bam Ferrovial Kier joint venture.

The machine was due to be dismantled over the following weeks as Tunnels went to press in early October, and the 130m-long trailer system will be removed from the tunnel via the recently completed Fisher Street shaft. Crossrail is asking Londoners to submit ideas for items to be included in a time capsule at the Farringdon site to mark the first completed tunnel.

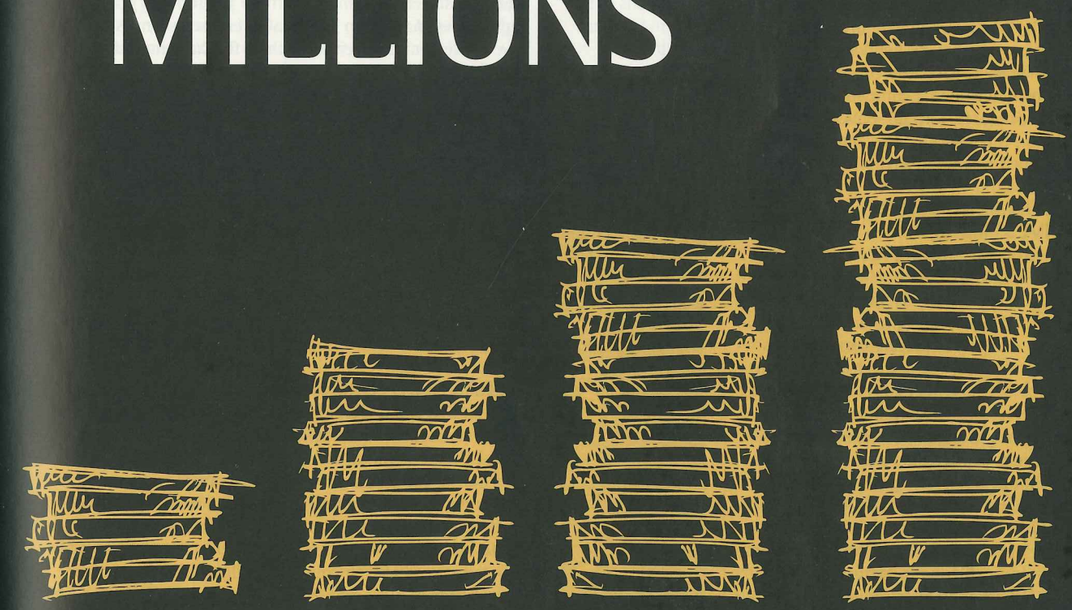
Andy Mitchell, Crossrail's programme director added, "This week, the final pre-cast concrete rings will be cast at Crossrail's temporary concrete segment factory for the western tunnels at Old Oak Common.

"More than 1,000 people are working on the western tunnel section of the project, building new train tunnels between Royal Oak at Farringdon, and new passenger, platform and service tunnels for new stations at Bond Street, Tottenham Court Road and Farringdon."

The Crossrail TBMs have collectively reached the halfway point of excavation, having tunnelled 21km of a 42km total. The other western tunnels TBM, Ada, was in the Holborn area as Tunnels went to press and was due to complete tunnelling during the winter, while the other six machines elsewhere on the project will finish tunnelling next year

Danny Richards, senior economist at *Timetric* takes a look at key trends in the infrastructure and wider construction markets in western Europe, with projections forward to 2017

EURO MILLIONS



Danny Richards
Danny is an economist at Timetric, the market analysis arm of *Tunnels* publisher WMI

WESTERN EUROPE experienced a severe financial crisis during 2008–2009, with economic activity in the region contracting sharply. Reflecting ongoing weakness in the region, real gross domestic product (GDP) has yet to rise above the pre-2008 level, with ongoing debt problems in most countries constraining growth, particularly in Greece, Ireland, Spain and Portugal.

Table 1. Infrastructure construction output

Year	Amount (USD millions)
2008	535,312.2
2009	484,821.2
2010	430,906.6
2011	455,155.6
2012	414,250.0
2013	415,537.0
2014	422,396.7
2015	432,890.4
2016	445,735.7
2017	460,550.4

Source: Timetric

Budget deficits and government debt in several countries in the region are at alarming levels owing to the sluggish recovery from the economic crisis, which has led to record high unemployment levels. Public and private investment for new projects has declined significantly in the recent past. The construction industry recorded a compound annual growth rate (CAGR) of -5.94 per cent during the review period, mirroring the subdued economic environment.

INFRASTRUCTURE INVESTMENT

Governments invested heavily in infrastructure development before the economic crisis. While spending has declined significantly, it still remains high, with infrastructure construction accounting for the second-largest share of the overall construction market in the region in 2012. The Netherlands and Belgium are looking to consolidate their positions as major logistics destinations in Europe by investing in the further development of intermodal transport. Large investments in rail infrastructure development in most western European countries – Germany, Spain, Sweden, the Netherlands, Belgium and France in particular – will see rail infrastructure construction record the fastest growth of all infrastructure construction categories over the forecast period. All members of the region are committed to increasing the share of renewable energy in total energy consumption and the energy and communication buildings category is set to receive healthy investment.

Construction activity over 2013 and 2014 is expected to move at a very sluggish pace as austerity measures adopted by different countries to control the rising level of public debt are expected to hamper growth in all construction sectors. Of the few positive factors, inflation in the region has been fairly stable and nearer to central banks' targets of two per cent. High unemployment rates in the region have also kept labor costs under control. Relative stability in input costs has also provided some respite for the construction industry. Timetric expects the western European construction industry output to value USD 2tn in 2017 and record a CAGR of 1.79 per cent over the forecast period.

414
The 2012 value in USD billions of the western European infrastructure sector

26%
Spain's share of the infrastructure construction market, the largest in western Europe

CONSTRUCTION INDUSTRY ANALYSIS

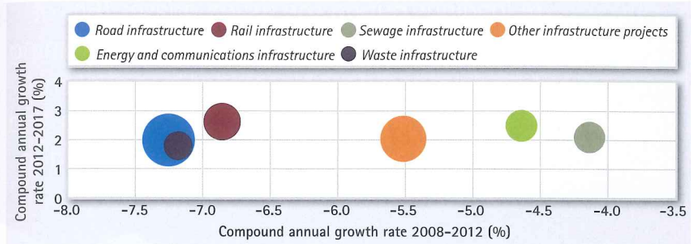
The western European construction industry valued at USD 1.9tn in 2012, recording a CAGR of -5.94 per cent during the review period. All construction markets registered negative growth in this period, largely as a result of the slowing down of the region's economies following the financial crisis and the region's debt troubles.

Infrastructure construction accounted for 22.3 per cent of the overall construction industry output in 2012. The market valued USD 414.3bn in 2012 and recorded a CAGR of -6.21 per cent during the review period. Countries across the region have invested heavily in infrastructure construction, and while investment has slowed since the financial crisis, it remains high. The Netherlands and Belgium are investing in further improving their infrastructure to maintain their positions as major logistics destinations in Europe. Governments across the region have implemented schemes, such as the National Infrastructure Plan (NIP) in the UK and the Strategic Infrastructures and Transport Plan (PEIT) in Spain, to support the infrastructure market. Large investments in rail infrastructure development in most Western European countries – Germany, Spain, Sweden, the Netherlands, Belgium and France in particular – will see rail infrastructure construction record the fastest growth of all infrastructure construction categories over the forecast period. All countries in the region are also committed to increasing the share of renewable energy in total energy consumption, and the category is set to receive healthy support. Timetric expects infrastructure construction to be the fastest-growing construction market over the forecast period with a CAGR of 2.14 per cent.

INFRASTRUCTURE CONSTRUCTION MARKET ANALYSIS BY COUNTRY

The infrastructure construction market in western Europe valued USD 414.3bn in 2012 with a CAGR of -6.2 per cent during the review period. The French infrastructure construction market valued USD 75.1bn in 2012, and with an 18.1 per cent share it was the largest infrastructure market in Western Europe. The French government aims to curb public spending to reduce the country's budget deficit to 4.4 per cent of GDP in 2012 and three per cent of GDP in 2013. The negative effects of this development are expected to be offset by growing investments in infrastructure by alternative sources of financing such as infrastructure-focused private equity and pension funds, and public private partnerships (PPPs). The French infrastructure market is expected to remain the largest infrastructure construction market in Western Europe, valuing USD 85.4bn in 2017 after recording a CAGR of 2.59 per cent over the forecast period. The Netherlands and Belgium are looking to consolidate their positions as major logistics destinations in Europe by investing in the further development

"Rail projects accounted for 30.6 per cent of the [infrastructure] market value"



Above: Figure 1, The compound annual growth rates of the past five, and next five years plotted against eachother

of intermodal transport. Large investments in rail infrastructure development in most western European countries, Germany, Spain, Sweden, the Netherlands, Belgium and France in particular, will see rail infrastructure construction record the fastest growth of all infrastructure construction categories over the forecast period.

All members of the region are committed to increasing the share of renewable energy in total energy consumption, and the category is set to receive healthy investment. Timetric expects the infrastructure construction market to record a CAGR of 2.14 per cent over the forecast period.

The French government is struggling to reduce public debt and the economy is forecast to contract over 2013. According to the budget announced in October 2012, there will be an average 15.6 per cent reduction in investment across all transport modes. The rail infrastructure budget is expected to fall by 26 per cent from USD 6.6bn in 2012 to USD 4.9bn in 2013, but will still remain the government's top priority with a 50 per cent share of the total budget. Rail infrastructure is receiving significant investments, as construction company Eiffage secured a EUR 3.4bn (USD 4.52bn) contract to build a 214km rail line between Le Mans and Rennes. As a result of this and other rail projects, the rail infrastructure category is projected to be the fastest-growing infrastructure category in France after recording a CAGR of 3.67 per cent over the forecast period. Preparation for the UEFA Euro 2016 football tournament is also anticipated to support investment in France's infrastructure construction market. A sum of EUR 1.7bn (USD 2.26bn) will be spent on repairing and refurbishing the 12 stadiums that will host the matches.

In the French energy segment, investments will be supported by the state-owned Electricité de France (EDF). Additional private participation is expected to continue to increase in the renewable sector, especially in solar power. France needs to increase the share of renewable energy in its gross final consumption of energy from 13 per cent in 2012 to 23 per cent in 2020. While renewable energy investment in France fell by 35 per cent to USD 4.3bn in 2012, over 90 per cent of the total investment was directed toward solar energy, which recorded an increase of 900MW in capacity. Meanwhile, wind energy capacity increased by 700MW in 2012. The energy and communications infrastructure category is projected to record a CAGR of 3.13 per cent over the forecast period and value USD 9.2bn in 2017.

Spain

With a 26.3 per cent share in western Europe, Spain was the largest infrastructure construction market in 2008. While investments still remain high, they have declined significantly. Spain's infrastructure construction market recorded a CAGR of -17.40 per cent during the review period and accounted for 15.8 per cent of the western European infrastructure construction market in 2012, the second-largest behind France which accounted for an 18.1 per cent share. Spain has invested heavily in infrastructure over the last two decades. In 2004, the Spanish Ministry of Development introduced the Strategic Infrastructures and Transport Plan (PEIT) 2005–2020, focusing heavily on enhancing rail, road and air infrastructure. The PEIT aims to develop a high-performance rail network across the country. Spain now has the longest high-speed railway network in Europe and the second largest in the world, after China.

There has been some criticism of the high-speed rail network, with opponents claiming that it runs around Madrid and not on commercially active routes.

A number of international airports that have been constructed remain unused and Spain now has double the volume of international airports of Germany. Rail infrastructure is projected to be the fastest-growing category in the Spanish infrastructure market with a forecast CAGR of 1.54 per cent.

United Kingdom

In the UK, the government launched the National Infrastructure Plan (NIP) in 2010, in a bid to create jobs and boost the economy. The plan was updated in 2011 and sets out a pipeline of 500 infrastructure projects to be implemented across the UK. An estimated investment of GBP 250bn (USD 401bn) will be needed to implement the NIP. Major investments will be made in highways, railways, nuclear, offshore wind farms and broadband networks. The Olympic site in London is to be converted into a business and residential area with around 40,000 homes built in the vicinity. This will relieve pressure on local housing and provide much-needed employment opportunities. This phase of development is expected to take place over two decades and will boost the construction industry. The infrastructure construction market in the UK is projected to value USD 28.7bn in 2017 after recording a CAGR of 1.59 per cent over the forecast period.

MARKET DYNAMICS

Within the western European infrastructure construction market, road infrastructure was the largest category in 2012, accounting for 30.6 per cent of the market value. Road infrastructure also recorded the largest decline during the review period with a CAGR of -7.27 per cent. Rail infrastructure is expected to be the fastest-growing infrastructure construction category over the forecast period with a projected CAGR of 2.61 per cent

The Second Coen Tunnel must survive severe loadings during the usage phase: 16m of water in the middle of the North Sea Canal and 8m of soil at the banks. The determining design scenarios were the sea transport of two days and possible impact by a sunken ship. This article goes into the general immersed tube principle and the construction and transport phases. The usage phase will be covered in the next article, to be published in an upcoming issue of *Tunnels*

EXTREME IMMERSION DESIGN

Authors
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THE SECOND Coen Tunnel in the A10 orbital motorway around Amsterdam is part of the larger project 'Capacity Expansion of Coen Tunnel'. As well as the construction of the Second Coen Tunnel, the scheme includes the renovation of the First Coen Tunnel, the expansion of seven existing structures, and the building of nine new structures. Some 11km of noise screen is also being realised. In combination with the construction of the Westrandweg four-lane motorway bypass, all this is intended to ensure better traffic flow around Amsterdam towards the rest of North Holland province. Commissioned by the Rijkswaterstaat public works entity, the project is being designed, built, financed and maintained in the context of a public-private partnership (DBFM contract) by the Coentunnel Company, a consortium of Arcadis, Besix, CFE, Dredging International, Dura Vermeer, TBI Bouw and Vinci Grands Projects. The design and realisation of the works is being carried out by Coentunnel Construction, a conglomerate of the construction companies Besix, CFE, Dredging International, Dura Vermeer, TBI Bouw, Vinci Construction and Croon Electrotechniek.

DESIGN OF IMMERSED TUBE TUNNEL

The main elements of the Second Coen Tunnel are:

- Northern approach (183m): open tunnel tray;
- Transition structure (50m): closed tunnel with service building and pump chamber;
- Immersed tunnel (714m);
- Transition structure (50m): closed tunnel with service building and pump chamber;
- Southern approach (273m): open tunnel tray.

The realisation of the Second Coen Tunnel started in 2008 with the preparation of a design for the immersed tunnel and the approaches. The immersed tunnel consists of a number of tunnel elements that are built in the construction dock and transported by water to the site. The construction of the immersed tunnel elements took place at the construction dock in Barendrecht. This construction location immediately brought with it a number of prior conditions, such as restriction of the element dimensions in connection with transit through the sea locks at IJmuiden, and also requirements concerning transport over the open sea (the North Sea).

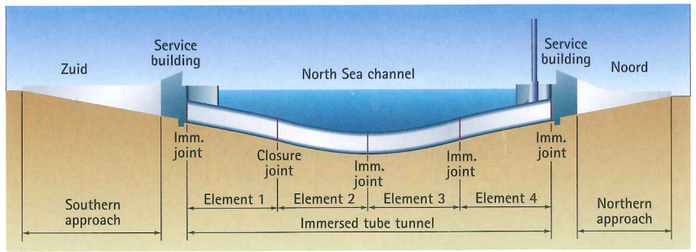
Due to its final location in the North Sea Canal, as well as the usual soil and water loadings, account also had to be taken of the possible sinking of seagoing vessels sailing through the said canal, and of anchors being dropped.

A 30m-high chimney was also built on to one of the segments for the extraction of exhaust gases.

The main dimensions of the tunnel elements were determined at an early stage. The immersed part was made as long as possible, in order to allow as large a part of the tunnel as possible to be prefabricated. To reduce the number of immersion operations, the tunnel elements had to be as long as possible. The length was however restricted by the dimensions of the construction dock in Barendrecht and the Noordersluis sea lock to be traversed at IJmuiden. Besides this, a greater element length leads to greater forces (bending and shear) during the sea transport and immersion. It was finally opted for four tunnel elements of 178.5m, each assembled from seven segments 25.5m long. The tunnel cross-section comprises two vehicle tubes and one central tunnel channel, and is characterised by its asymmetrical shape (see Figure 2).

Above: Immersion of a tunnel element

11
Kilometres of noise screening that will be required for the project as a whole



Below: Figure 1, Arrangement of elements and joints along the immersed tunnel

BASIC CONSTRUCTION PRINCIPLE

From a structural viewpoint, the Second Coen Tunnel is a chain of stiff structural elements (segments) on a flexible bed. The segments are separated from each other by three types of joint: immersed joints between the tunnel elements; segment expansion joints between the segments; and a closure joint where the tunnel is closed after the immersion of the last element.

The joints provide flexibility to the structure, so that bending moments remain limited. To avoid differential subsidence, teeth are introduced into the joints, to transfer both horizontal and vertical transverse forces. The tunnel is kept watertight by rubber seals. A steel-rubber seal strip is applied round the entire circumference of the segment joints, with the possibility to inject this further afterwards. An initial water seal in the immersion joints is ensured by the GINA gasket. After finishing the joint structure, a permanent water seal is applied in the form of an Omega section (Figures 3 and 4).

Both the tunnel segments and the joints between them are dimensioned for two situations:

1. The temporary building phase including floating off, transport and immersion;
2. The usage phase, including incidents that may happen during the lifetime.

This complex and laborious design process demands great precision. A balance must continually be found between opposites that often concern differences between these two design situations.

OPPOSITES

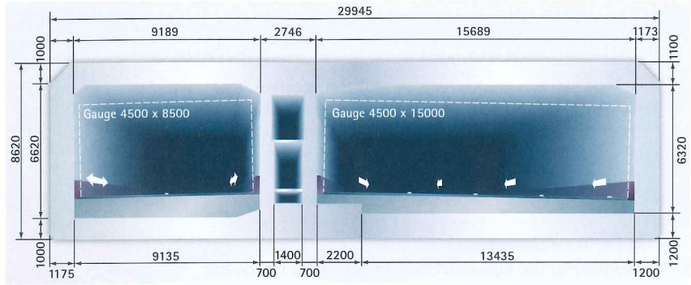
With an eye on the floating transport, the tunnel elements must be light enough to be transported in both fresh and salt water with sufficient freeboard (the part that remains above water during transport). Too little freeboard makes the tunnel elements unstable. However, after immersion, the tunnel elements must remain solidly on the canal bed. This contradiction is bridged by designing the tunnel cross-section such that the relationship between concrete volume and water displacement comes out favourably for the freeboard, while still providing enough space to ballast the tunnel with water during immersion, and to provide it with a layer of concrete ballast in the final situation. A third criterion follows naturally from the requirement that the tunnel cross-section must not only be able to bear the soil and water pressures, but also emergency loadings such as an anchor being dropped or a sinking ship. The designers also had to take account of the actual specific weight of the concrete including reinforcement, the salt content of the water, and the actual concrete dimensions in relation to the concrete weight and water displacement.

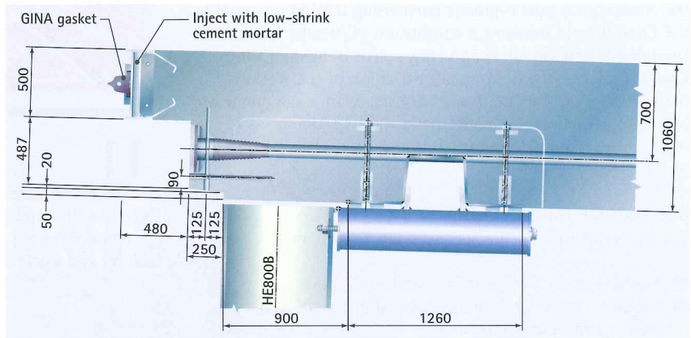
Another design task arose from the desire that the tunnel elements should behave as a single unit during floating off, transport and immersion, but should lie like a flexible 'vacuum-cleaner hose' on the canal bed in the final situation. This is to avoid large forces in the structure. For this reason, the tunnel elements were provided with expansion joints between the segments at regular spacings, with the segments being held together by transport pre-stressing.

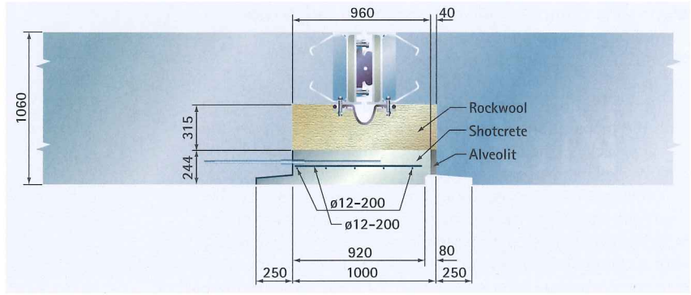
This pre-stress was then removed after immersion by cutting through the cables.

RELATIONSHIP BETWEEN TRANSPORT AND DESIGN

The realisation of a tunnel element that is suitable in both the final and the building phases is a supremely challenging balancing exercise.







Above, top: Figure 2, Schematic cross section

Above, middle: Figure 3, Immersion joint in the roof, temporary setup. With pre-stress anchor and recess for bulkhead stop

Above, bottom: Figure 4, Immersion joint in the roof, final situation. The Omega section gives a permanent seal. Finished with reinforced concrete

This section describes the temporary design situation, namely the floating off, transport and immersion of the tunnel elements.

In order to carry out this assessment properly, all forces and stresses in the temporary building and transport phases must be correctly mapped out using a scheme that is followed meticulously during each building and transport action, including:

1. The construction of the elements themselves
2. The floating off of the elements in the construction dock
3. The transportation of the elements to their final location
4. The immersion of the elements
5. The ballasting of the tunnel elements and the completion of the tunnel, taking into account the later maintenance regimes.

As well as the preconditions listed earlier for the dimensions of the tunnel elements, their stability (rotational too) during floating off, transport and immersion is of importance.

Next, the various temporary building and installation phases are described, to consider their influence on the design of the tunnel elements.

FLOATING OFF

The elements of the Second Coen Tunnel are constructed on a gravel bed in the construction dock (see photo, below). The height of the elements is 8.6m, so that the top of the roof is about 1.4m below NAP (Amsterdam ordnance datum). The water level during floating off (at low tide) varies between 0.5m above and below NAP.

The distance over which the element must be raised to have its roof protrude above the waterline with a freeboard of 0.20m (tunnel elements (TE) 1 and 4) is between 1.1 and 2.1m; that for a freeboard of 0.9m (TE2 and TE3) is 1.8 to 2.8m. When the ballast tanks are full, the elements are unstable as long as they are under water. Due to this, the risk exists that they will float up rotated about their longitudinal axis.

Because the elements are vertically curved, the position of their rotational axis is not fixed. The risk therefore exists that the element might turn about a vertical axis too, so that the primary or secondary end would be displaced far to one side, causing it to hit the adjacent element. This risk applies especially to the sharply curved TE2 and TE3. For this reason, the elements are floated off from either the primary or the secondary end first. To prevent the element being able to rotate around its longitudinal axis during this, a ground reaction of 500t is maintained. Once the length of the part protruding above the water is sufficiently great to ensure waterline stability, the tanks at the opposite end are emptied.

The exact weight of the tunnel element is equally crucial during the transport, immersion and final phases. The weight and centre of gravity of the tunnel elements are calculated based on the design drawings, and also verified through accurate monitoring of the amounts of concrete and reinforcement used while building the elements. This can also be calculated exactly during floating off, by combining the measured freeboard with the density of the water.

At each phase of the floating off of the elements and the filling of the construction dock, the tooth forces and the pre-stress forces are calculated and verified. In this, the timing of the injection of the pre-stress channels is important: if this is done before floating off, the friction between the floor and the ground underneath could prevent the joints being completely sealed. This is therefore done after floating off, which reduces the effective pre-stress force. Account is taken of this when determining the phasing. After checking, the effect of this phenomenon proved to be negligible as it happens. The transport pre-stressing is gone into later in the article.

8.6m
The height of the immersed tunnel elements, approximately 1.4m below NAP

Below: Barendrecht construction dock. First, the floor is cast, then the interior walls, and finally the outer walls and roof in one pour

TRANSPORTATION

Firstly, the transverse stability of the element to be transported is calculated, to ascertain whether it will try to rotate about its longitudinal axis during the transport phase, and to what extent this phenomenon is sensitive to the variation of parameters. To this end, a calculation is performed for each element, in which the element's reactive torque is calculated as a function of its rotation about its longitudinal axis (on the waterline):

- Determine the weight and the centre of gravity of the element, based on the survey of the geometry realised, and its verification during floating off;
- Calculate the position of the centre of gravity with respect to the pressure point as a function of the element's angular rotation;
- The reactive torque is equal to the product of the water displacement times the horizontal distance between the centre of gravity and the pressure point.

It emerged from this calculation that all elements were rotationally stable during the transport phase.

Transport stresses

Secondly, the influence of wave loadings on the tunnel elements during transport is calculated. This is to investigate whether the number of pre-stressing cables present would be sufficient for the sea transport.

These calculations comprise the following steps:

- The wave picture at sea is represented by a wave spectrum built up from a large number of regular waves each with its own height and period.
- Via Fourier transformation, the time series of the water level is converted into a spectrum. The energy of each frequency band is given in this spectrum (though the disadvantage of this is that the phase relationship among the waves is lost).
- It has been established for the North Sea that a spectrum is generally described by the peak period of the spectrum and the significant wave period.
- The spectra can be normalised to

Left: Immersed element reinforcement

a wave height of 1m. These spectra are therefore solely dependent on the peak period. There is thus a relationship between the spectrum and the significant wave period.

- Responses: in a mental model, all forces and movements are determined for regular waves, each with a different wave direction and period, but with a fixed significant wave height of 1m.

In this way, the responses for all relevant wave periods are found. Because the responses are assumed to be linear to the wave height, the transfer function from wave to response is found. Fourier transformation of the responses now yields the response spectrum, analogously to the wave spectrum. The computational model takes account of all the phenomena arising that determine the loading, such as the throwing up and reflection of the waves, the movement of the element, and the effect of the solid seabed.

- The workability spectrum (sailing criterion) kept to for sea transport is defined by a significant wave height H_{sig} = 2.0 m with peak period T_{peak} = 6.0 s; the survival spectrum by H_{sig} = 3.0 m and T_{peak} = 9.0 s.

Transport pre-stress

To these wave loadings is added what is known as sailing loading: the effect that a tunnel element pitches over into the 'potential well', the water level drop as a result of flow around the element. The transport stresses calculated in this way are scaled up based on a comparison with a project for which both calculations and model tests have been done.

In order to keep the tunnel segments together during floating off, transport and immersion, a transport pre-stress is applied. This pre-stress is designed such that under operational sea conditions, no joint gaps arise (criterion: minimum pressure of 0.2N/mm²), and that in the 'survival situation', no cable failure occurs. The pre-stress is applied to the floor and roof of the tunnel. In order to give the tunnel the opportunity to 'settle' on the canal bed, the pre-stress cables are cut. Because the pre-stress channels are injected, the cutting of the pre-stress cables means that the entire pre-stress force at the start and end of the segment will be transferred to the concrete (just as in the long-bed system in the prefab industry). Of course, this must be taken into account when specifying the reinforcement in floor and roof; once again an example of the effect of the transport conditions on the design of the concrete structure. At transportation time, following the weather report (forecast) was therefore of crucial importance, to assess whether it fitted with the sailing criterion. Before departure from the construction dock, it was decided, based on the weather forecast for the coming 48 hours, whether the transport could proceed. Another forecast update followed just before venturing into the North Sea, to determine whether the voyage could continue.

IMMERSION

Each element has four ballast tanks each with a volume of 1000m³. The capacity of each of the four lifting points on the ballast tanks is 100 tons. The corner bitts, which are sited on the same cast-in foundations as the towing points for the sea tow, have a working load of 100t.

For the elements, two immersion pontoons with a waterline area of 200m² were used. The pontoons were fitted with immersion winches. The tanks were filled by workers in the element itself. During slacking off, the elements were subjected to an upwards force that increased with depth, as a result of the increasing salt content of the water. To guarantee sufficiently-high immersion loadings, more ballast water was allowed in when needed. The shear forces in the elements corresponding to such phasing were also calculated and verified. For the two boundary elements, the immersion pontoons were sited on the secondary end. After the element had been shifted along the immersion trench to over its desired position, container pontoons were placed on the deck at the primary extremity. During immersion, the freeboard was first reduced by letting water into the ballast tanks.

The container pontoons were filled with water to keep them weighted down on top of the element with sufficient pressure during the immersion process. The entire deck was taken under water by letting water into the tanks.

The primary end was lowered in steps by letting water into the tanks. The secondary end was lowered using the lifting system on the immersion pontoons. For the two elements in the middle of the North Sea Canal, the immersion pontoons were placed at the primary extremity, while the floating sheerlegs was made fast to the secondary extremity.

After each tunnel element was immersed, it was supported temporarily at one end by a projection on the previous element, and at the other by two adjuster feet, so that a gap of about 0.5m was present beneath it. Shortly after immersion, this space was injected with a sand-water mixture through openings that had been made on the underside of the element, staggered to left and right. A 'sand pancake' was made through each opening. This flowing-in is a meticulous process, in which the viscosity of the flush and the flow rate of the water play important roles. The final quality of the individual pancakes differed, so that the foundation's stiffness was not uniform.

It is clear that the building phase, including the transportation of the tunnel elements, has an enormous impact on the design of an immersed tube tunnel, and the design task is a combination of complex considerations and verifications

editor@tunnelsonline.info

What do you think? Send your views to the editor and join the debate

STUVA PREVIEW

Every two years STUVA hosts a tunnelling conference and the 2013 edition takes places this month in Stuttgart, Germany

INFRASTRUCTURE FOR the future is the theme for this year's STUVA conference in Stuttgart. "Progress requires mobility. And societal acceptance of investing in infrastructures is needed to create mobility. After all, our prosperity is undoubtedly based on a functioning infrastructure," say STUVA's Martin Ziegler, chairman of the board, and Roland Leucker, managing director.

Held on odd-numbered years, the conference attracts more than 1,500 participants and visitors from about 20 different countries. Registration is now open, online for the three-day event on November 27-29. Lecture topics range from major international projects to tunnelling in safety, and a section related to underground work locally in Stuttgart. Other events include the STUVA 2013 prize and a number of options for field trips on the final day. Check out *Tunnels*' guide to the conference and trade show


Stuttgart cityscape

27-29 November
International Congress Centre
Stuttgart, Germany
www.stuva-conference.com

Schedule

Date		*Programme*
Wednesday, 27 November 2013	9:00	**Opening** Univ.-Prof. Dr.-Ing. Martin Ziegler, chairman of the Board STUVA e.V., Köln **Welcoming address** Opening lecture: Tunnel Infrastructure for the Future – Contribution of the DB Ag awarding of the 2013 STUVA Prize
	10:30 - 11:45	Break
	12:00	Question round
	12:15	Lunch break
	14:00 - 15:15	Safety in tunnelling – 40 Years German tunnelling
	15:30	Question round
	15:45	Break
	16:15 - 17:00	Youth forum
	17:15	Question round
	17:30	End of presentations
	19:30	Reception for the participants of the festive evening
	20:00	Festive evening and awarding of the 2013 STUVA Prize for young engineers
Thursday, 28 November 2013	9:00 - 10:00	Mechanised tunnelling
	10:15	Question round
	11:00 - 11:45	Urban construction and tunnelling
	12:00	Question round
	12:15	Lunch break
	14:00 - 15:30	Civic participation, legal and contractual issues
	15:45	Question round
	16:00	Break
	16:30 - 17:45	Underground construction in Stuttgart
	18:00	Question round
	18:15	Closing remarks Univ.-Prof. Dr.-Ing. Martin Ziegler, chairman of the Board STUVA e.V., Köln

Field Trip

On Friday conference participants are invited to take part in one of the conference's excursions (listed as options A-L to the right).

The number of participants for each excursion is restricted and reservations are accepted on a first-come, first-served basis Excursions A-K will start between 8.00 and 10.00 am and end between noon and 1.00 p.m., and be conducted only in German. Trip L, the site visit to Herrenknecht's headquarters, will be conducted in English and German, and require extra travel time.

Excursions

Excursions in conjunction with the Project Stuttgart – Ulm

A. The Wagenburg tunnel in the Filder tunnel Project Approval Section (PFA 1.2)
B. Ulmer Straße intermediate Point of Attack in the ober- Untertürkheim Project Approval Section (PFA 1.6a)
C. North intermediate Point of Attack in the Feuerbach and Bad Canstatt Project Approval Section (PFA 1.5)
D. the Boßler tunnel in the Albaufstieg Project Approval Section (PFA 2.2)
E. the Steinbühl tunnel in the Albaufstieg Project Approval Section (PFA 2.2)

Excursions in and around Stuttgart

F. the new U12 Metro Line beneath the Europa District
G. Improving Safety Standards in the Heslach road tunnel
H. The Integrated Traffic Control Centre Stuttgart
J. Mastering Methane gas in the Scheibengipfel tunnel
K. The MercedesBenzWorks in Sindelfingen
L. Tunnel giants from Schwanau

Exhibitors

Exhibitor	*Stand*
3D Mapping Solutions GmbH	B103
A.S.T. Bochum GmbH	A103
ACO Tiefbau Vertrieb GmbH	E102
AGRU Kunststofftechnik GmbH	D101
Albatros Engineering GmbH	B107
Amberg Engineering AG	D130
Amberg Technologies AG	D130
ANIXTER - Sofrasar	C109
Atlas Copco MCT GmbH	C131
Austin Powder GmbH	B127
ave Verkehrs- und Informationstechnik GmbH	G126
Babendererde Engineers GmbH	G104
BASF Construction Polymers GmbH Geschäftsbereich Betonzusatzmittel	G111
BAUER Spezialtiefbau GmbH Geschäftsbereich Technik/Technology Division	G101
Bauverlag BV GmbH	C132
Belloli SA	E110
Bilfinger Construction GmbH Niederlassung Tunnelbau	E104
BK Giulini GmbH	E108
Bochumer Eisenhütte Heintzmann GmbH & Co. KG	E130
Böhm Fertigungstechnik Suhl GmbH	C107
Bonar GmbH & Co. KG	B112
BPA GmbH	D128
BUNG Ingenieure AG	C108
CDM Smith Consult GmbH	D131
CFT GmbH Compact Filter Technic	C117
Clariant Produkte (Deutschland) GmbH	C136
Dätwyler Sealing Technologies Deutschland GmbH	F103

Exhibitors

DB International GmbH	B118
DB ProjektBau GmbH	G105
De Neef Conchem bvba	F132
Deilmann-Haniel GmbH	E128
Deilmann-Haniel Mining Systems GmbH	B133
Dipl.-Ing. Bernd Gebauer Ingenieur GmbH	F111
DMI Injektionstechnik GmbH	A104
Dr. Spang GmbH	E107
Drägerwerk AG & Co.KG	B129
Durstmüller GmbH	E101
Dywidag- Systems International GmbH	D129
Ed. Züblin AG	D102
EDR GmbH	F107
Ein Shemer Rubber Industries Ltd	G122
Elkuch Bator AG	D106
Encardio Rite Electronics Pvt. Ltd	A105
EPLASS project collaboration GmbH	D108
Ernst & Sohn, Verlag für Architektur und technische Wissenschaften GmbH & Co. KG	B136
Fermacell GmbH Fermacell Aestuver	A112
FIDES DV-Partner Beratungs- und Vertriebs-GmbH	G131
FOGMAKER INTERNATIONAL AB	B117
FOGTEC Brandschutz GmbH & Co. KG	D105
G quadrat Geokunststoffgesmbh	D101
GEODATA Group	D129
GEOKON Inc. c/o Scanrock GmbH	B110
germanBelt Systems GmbH	D104
GHH Fahrzeuge GmbH	F130
GLÖTZL Gesellschaft für Baumeßtechnik mbH	F127
Grontmij GmbH	E112

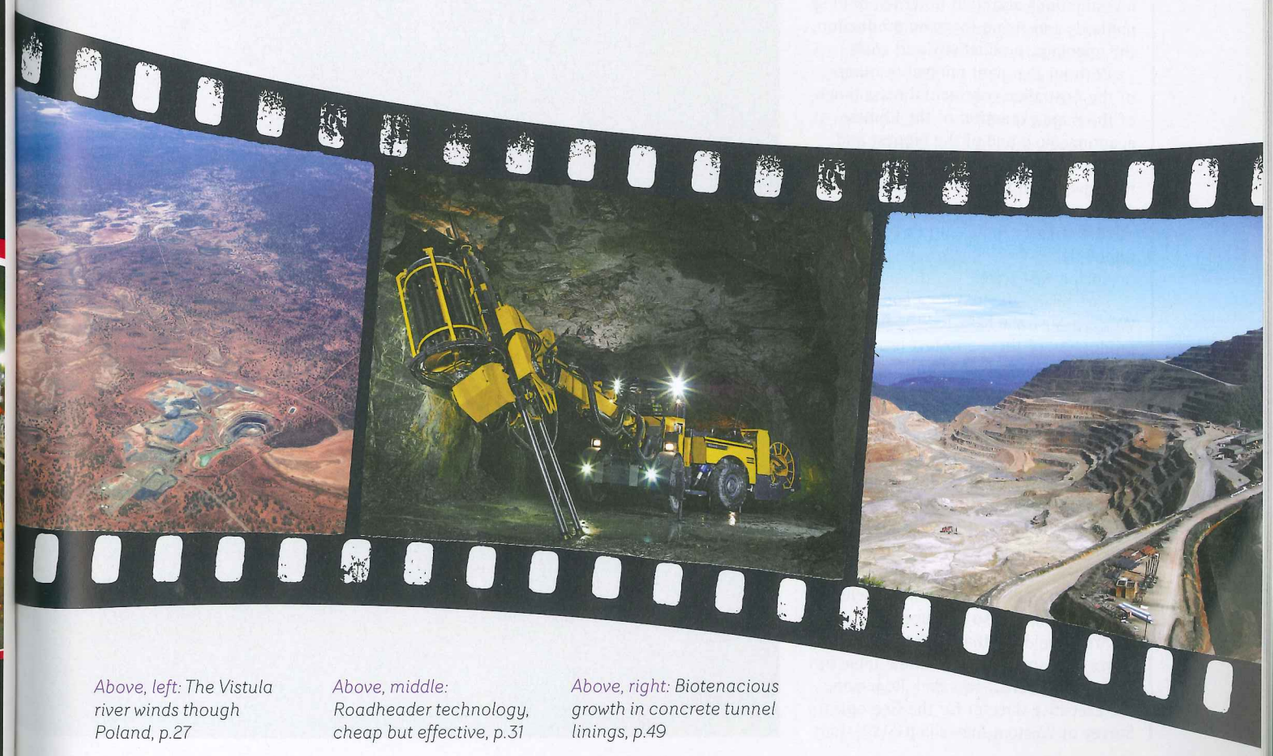
Exhibitors

Gruner AG Ingenieure und Planer	D103
GSE Lining Technology GmbH	D111
GTA Maschinensysteme GmbH	A111
Güssow-Voyé Drucklufttechnik GmbH	G114
GWE pumpenboese GmbH	G107
H-BAU Technik GmbH	C104
Ha-Be Betonchemie GmbH & Co. KG	E108
HALFEN GmbH	B114
HANNING & KAHL GmbH & Co. KG	G120
HBI Haerter – Beratende Ingenieure	F114
Herco Kühltechnik GmbH	C114
Herrenknecht AG	C116
Herrenknecht Formwork Technology GmbH	C116
Hochtief Solutions AG	A106
Hodapp GmbH & Co. KG	C115
Hölscher Wasserbau GmbH	F128
IFAB Ingenieure für angewandte Brandschutzforschung GmbH	F112
IMM Maidl & Maidl Beratende Ingenieure GmbH & Co. KG	B130
Implenia Schweiz AG Tunnelling & Civil Engineering	F105
Ingenieurbüro Dipl.-Ing. H. Vössing GmbH	E106
InnoTrans 2014	C112
Interfels GmbH	G112
intermetric GmbH	F106
ITC SA - Inter Techno Commerce SA	B105
ITE GmbH	A115
itmsoil Interfels	G112
Jähnig GmbH Felssicherung & Zaunbau	B113
JENNMAR Corporation	G117
JORDAHL GmbH	C104
Kapyfract AG	C105
Keller Grundbau GmbH	E109
Kern Tunneltechnik SA	F129
Korfmann Lufttechnik GmbH	C117
KrampeHarex GmbH & Co. KG	G106
KSE-LIGHTS GmbH	B104
KTI-Plersch Kältetechnik GmbH	F104
Langmatz GmbH	G129
Leica Geosystems GmbH Vertrieb	B116
Liebherr-France SAS	F110
LKAB Minerals GmbH	B119
MAPEI GmbH	A101
Max Bögl Bauunternehmung GmbH & Co. KG	D132
MAXAM Deutschland GmbH	G114

Exhibitors

MC - Bauchemie Müller GmbH & Co. KG	A107
McDowell B. Equipment	E103
Minova CarboTech GmbH	G102
Minroc Bohrausrüstungen GmbH	G116
Mooser Schwingungstechnik GmbH	C103
NAUE GmbH & Co. KG	E105
Normet International LTD.	C111
Obermann GmbH	A102
OBERMEYER Planen + Beraten GmbH	D110
OSMO-Anlagenbau GmbH & Co. KG	B102
Palmieri S.p.A.	B108
Patrona Versicherungsvermittlungs-GmbH	C101
Pressluft Frankfurt Drucklufttechnik GmbH	G124
Promat GmbH	C133
Putzmeister Concrete Pumps GmbH	F129
Rascor (Deutschland) GmbH	E127
RK safetec GmbH	G113
Rockmore International GmbH	G121
Rowa Tunnelling Logistics AG	E110
S & B Industrial Minerals GmbH	G103
Sandvik Mining and Construction Central Europe GmbH	C102
Schauenburg MAB GmbH	B111
Schauenburg Tunnel-Ventilation GmbH	C114
Schüßler-Plan Ingenieurgesellschaft mbH	A110
Sika Deutschland GmbH	F130
SOFiSTiK AG	G131
Söndgerath Pumpen GmbH	C103
SSF Ingenieure AG Beratende Ingenieure im Bauwesen	F101
StekoX GmbH Abdichtungstechnik	E126
STS Scheltzke GmbH & Co. KG	F102
STS Spezial-Tiefbau-Systeme GmbH	G108
STUVA	G134
Swibox AG	F116
The Robbins Company	B101
TPH Bausysteme GmbH	D107
Tsurumi (Europe) GmbH	A113
VersuchsStollen Hagerbach AG	D130
VMT GmbH Gesellschaft für Vermessungstechnik	F108
Wayss & Freytag Ingenieurbau AG	F109
WBI Prof. Dr.-Ing. W. Wittke Beratende Ingenieure für Grundbau und Felsbau GmbH	A109
Webac-Chemie GmbH	A114
Zeppelin Baumaschinen GmbH	B109
Zeppelin Rental GmbH & Co. KG	B109
ZERNA Unternehmensgruppe	C118

MINING Supplement



Above, left: The Vistula river winds though Poland, p.27

Above, middle: Roadheader technology, cheap but effective, p.31

Above, right: Biotenacious growth in concrete tunnel linings, p.49

GOLDEN SOIL AND WEALTH FOR TOIL

Few countries have as many mineral resources as Australia, and in such quantities, from coal and oil to iron, gold and nickel. Mining and other extraction is an increasingly large part of the economy, reports technical journalist **Adrian Greeman**

Adrian Greeman
Is a former editor of and long-standing regular contributor to *Tunnels*

IN LOOKING to develop a mineral prospect, a number of factors need to be determined and weighed in balance, including geology and mineralogy at the time, and ore valuation forecasts over the various horizons for possible life-time periods of the potential mine. Into the planning investigations also goes potential mining methods and sizing for mine production, the openings, productivity and costs.

Without the giant mineral resources of the Australian continental mass much of the huge expansion of the Chinese economy, now one of the biggest and fastest growing in the world, might not not have taken place, at least on the 10 per cent per year rate it has. The same is true for India, almost equal in population even if its economy is not yet on such a vast scale.

Particularly the iron ore deposits of Western Australia have fed the industrial production of these two fast growing economies, along with supplying another Asian powerhouse economy, Japan, which remains a crucial customer. But coking coal from central Queensland, one of the world largest suppliers of high grade iron smelting coke coal, has been equally important. Energy resources including thermal coal deposits and increasingly gas, oil and other fuel supplies have also come into their own. New South Wales and to some extent the other states, also produce.

"You could say that we have just about every part of the periodic table in Western Australia," says Rick Rogerson, the executive director for the Geological Survey of Western Australia (GSWA), part of the state government's Department of Mines and Petroleum (DMP). There is oil and gas both onshore and offshore and all that is missing, he says, are high grade coal deposits. But these are amply made up by the giant coal bearing basins to the east.

According to the Australian government Web site the country overall has the world's largest reserves of brown coal, mineral sands yielding rutile and zircon, nickel, lead, silver, uranium, iron ore and zinc.

It has the world's second largest reserves of bauxite for aluminium and tantalum used in mobile phone production. For copper it comes up as the world's third largest reserve and for silver the fourth largest reserves of silver. It is also a significant gold producer, just outside the top three.

ABOVE THE CLOUDS

All this has meant that until recently Australia had managed, almost uniquely among Western economies, to ride out the impact of the 2008 credit crunch, or global economic downturn. Though its tourism, manufacturing and service sectors were hit like many others, its mining not only held up but was expanding significantly until this year. Some downturn was apparent in 2012 and there has been a significant slowdown in 2013, though still continuing on a large scale.

For the mining sector and mining services sector the year

179
The value in USD billions of the Australian mining and mining services industry

2011 showed one of the largest increases ever in exports, increasing over 15 per cent to a record AUD 190bn (USD 179bn), based on strong demand for minerals and commodities from China and other parts of Asia.

Overall GDP for Australia continued to rise, partly on the strength of this industry. Although it dropped back in the wake of the global recession to USD 923bn for the year to the middle of 2009 it increased subsequently to USD 1.14tn, USD 1.38tn to the middle of 2012 and USD 1.52tn this year.

But although it has held ground the impact of world trading difficulties also make themselves felt in Australia. The earlier part of 2013 has seen fallbacks in the mining industry and greater problems for the sectors servicing it, including the machinery sales. Boom conditions in the coalfields of Queensland have disappeared and local press reports suggest once highly-priced housing and apartments in mining areas have become much cheaper.

The picture is mixed. According to the international executive search and recruitment company Swann Global: "The number of people directly employed by the Australian mining industry has grown, reversing the contraction over the past two quarters." In February 2013 the Australian Bureau of Statistics estimated the total workforce to number 246,100 people, an increase of 4,100 in the quarter but still well short of the peak employment of 261,000 people recorded in May 2012.

The exports peak of AUD 190M (USD 179M) fell back in 2012–2013 to AUD 177bn (USD 167bn), according to the Australian government's Bureau of Resources and Energy Economics (BREE(in its Resources and Energy Quarterly for the June quarter.

According to BREE's executive director and chief economist, professor Quentin Grafton, "large fluctuations in equity and foreign exchange markets, coupled with weakening sentiment have negatively affected the price of some resource commodities, particularly precious and base metals." He says the largest fall was in the price of gold, "which declined in value by 12 per cent in one week during April."

Evidence of softening in the Chinese economy and concerns surrounding the tapering off of the US Federal Reserve's quantitative easing before the end of 2013 contributed to a more than 10 per cent depreciation of the Australian dollar relative to the March quarter 2013, the bureau goes on.

"While a depreciating dollar increases

the Australian dollar value of resources and energy exports denominated in US dollars, this was more than offset in 2013 by weakening commodity prices," Grafton says.

He adds that "the nominal value of resources and energy exports is forecast to increase by around 11 per cent to AUD 197bn USD (187bn) in 2013–2014. An assumed depreciation of the Australian dollar–US dollar exchange rate in 2013–2014 will provide support for Australian dollar denominated resource and energy exports."

A major factor now could well be a change in direction politically. The industry is now waiting to see what will happen with a new government in place. Elections at the beginning of September saw the end of a six-year period of Labor government at the federal level and a major victory for the Liberal-National Coalition of the new prime minister, Tony Abbott.

The conservative right wing government is likely to be more 'industry friendly', particularly over the confusing issue of the Minerals Resource Rent Tax. This was to be a tax on profits generated from the exploitation of non-renewable resources in Australia and was itself a replacement for a proposed Resource Super Profit Tax.

The tax, which levies a 30 per cent charge on 'super profits' from the mining of iron ore and coal in Australia, was introduced on 1 July 2012 but is heavily opposed by the mining companies and owners. In the election campaign the new government had promised to repeal the tax.

As well as allowing companies to keep more of the profits they generate, some Australian commentators suggest there could be an upturn in investment because of greater certainty. The tax has not only been contentious but was hampered in its early form by a fallback in mining industry profits just after its introduction.

Other issues that might now affect the mining industry are changes to the carbon tax to which the new government has a very different approach, according to Michael Roche, chairman of the Queensland Resources Council, an industry lobby group for the mining and energy sector representing about 90 companies large and small in the state.

Above: Australian mining is a significant proportion of world mineral exports

Opposite: Enormous 'land trains' serve the mining industry in Australia

"Things will depend very much on what the new government can pass in legislation as they do not control the upper house," he says, "but they would like to scrap the tax." This would be significant for mines, he said, which pay tax on methane emissions, and through altering the tax paid by emissions intensive industries, major users of coal.

There is also a possibility that there will be some 'modest' tax changes for exploration companies, he says. Particularly smaller companies, known as junior resource explorers, have been suffering from the squeeze on credit in the post 2008 financial atmosphere.

QUEENSLAND

The vast spaces of this 2,600km long Pacific seaboard state, covering 1.8Mkm², range from tropical humidity in the north to the surf and sunshine coastline around Brisbane. It is a major agricultural producer but increasingly exploits its minerals too.

Much of Queensland's mining activity focuses around coal in a number of major basins throughout the state though it also has substantial metal mining activity, particularly in the remote Mount Isa inland region. Activity includes silver, lead, zinc and copper, as well as three-quarters of the country's bauxite production putting the state at the fifth largest producer in the world. There are also substantial uranium deposits, which only recently were given the go-ahead for exploitation once again last year after a long ban.

The north-west minerals region is difficult and suffers from very dry conditions, which make water for operations difficult to find; it is also remote with a 1,000km rail journey needed to reach port access.

Gemstones exploration is also significant, including sapphires, though not diamonds.

"The right wing conservative government is likely to be more 'industry friendly', particularly over the confusing Minerals Resource Rent Tax"

For coal the state has vast resources in both high grade high carbon coking coal used in iron and steel production and in thermal coal for power stations. Some 34bn tonnes of reserves exist though much of this remains unexploited as yet. According to state government figures there were 54 operating coal mines in 2012, which produced 187.6Mt of saleable coal in 2011-2012. Of these export sales were 165M.t worth AUD 30.9bn (USD 29.3bn).

Mining and energy constitutes one fifth of the state economy, says Michael Roche, chief executive of the Queensland Resources Council, the main industry lobby group for the mining sector, based in Brisbane. It provides one in eight jobs

"We have 60 per cent of the Australian coal export and 25 per cent of all internationally traded coal."

He points out that that is only a tiny percentage of world production, at around three per cent.

"But we have the advantage of very high grade coal for coking and in that sector we produce 75 per cent of the world trade for the steel industry."

He believes the level of production will climb significantly yet perhaps reaching some 300-325Mt by 2020, though these figures could be affected by downturns currently hitting even the huge growth of China, which has dropped back to around seven per cent at present, still staggeringly high but a big fall from the past rates. India too has seen cutbacks and is facing a drop in the Rupee at present which may have serious implications for the future.

"The impact has been felt in the state," he says, declaring in June that the "industry was staring down the barrel of the worst operating conditions for more than a decade."

Despite this there are long term projects underway that he says will greatly expand coal capacity. These include further developments in the Bowen coal basin and as yet untapped coalfields such as the Galilee further inland and the Surat basin towards the south. For many of these potential investments there is a question of infrastructure to be able to move out the coal from the developments, including the need for railways and port expansion.

A number of the large companies are looking at gigantic investment schemes, says Roche. These include completely vertically integrated investments by companies like India's Adani, which intend to develop 60Mt per annum thermal coal mine in the north Galilee Basin in central Queensland.

All coal will be railed via a privately-owned rail line connecting to the existing Aurizon rail infrastructure near Moranbah, and shipped through coal terminal facilities at the Port of Abbot Point

"They are going from the mine to generating the electrons," says Roche, and "would build everything from the mine to the rail and port facilities to take the coal in Adani ships to Indian mainland power stations."

Meanwhile the jointly owned Indian-Australian GVK-Hancock Coal company is readying two similar projects. The Kevin's Corner project and the Alpha Project, also in the Galilee basin, and both producing over 30Mt per annum to be carried by a newly-built railway, again to the Abbots Point port facility where the scheme would build further shipping infrastructure. The mines would initially be open cut and then long wall underground mined.

"Huge volumes are needed to make these schemes cost effective," says Roche. Current economic conditions were not likely to affect the thinking on these schemes, and several others, because "they take a very long view."

Meanwhile the advent of underground fracking and other technologies is having a big impact in Queensland.

75%
Of coal for the world steel industry is produced by Australia

25%
Of all coal exported to international markets is mined in Australia

60%
Of the Australian coal exported is mined in Queensland

A number of technologies are under development for extracting gas and oil from the ground.

One of the major developments is the use of coal seam gas, which extracts existing methane in coal seams by drilling the reserves and draining the groundwater. The geologically trapped gas can escape along with the dewatering and is separated at surface. It is a technique that allows significant energy recovery from otherwise inaccessible coal seams, says Roche.

Alongside this is the development of underground coal gas. This is a very different technology involving controlled combustion within a coal seam to convert coal to gas.

A vast number of exploration wells and significant production has already begun for these methodologies, though they can be controversial and have provoked protests, as they have elsewhere in the world. But plans are well advanced for the export of the gas in liquefied form with three major liquefying plants recently completed or under construction at the port of Gladstone (see page 47), at a cost of around AUD 45bn (USD 42.6bn). A fourth scheme to sit alongside the others is in design by Arrow Energy, a joint venture between Shell and Petro China.

The four units are part of major expansion works located at Gladstone, which is also seeing significant increased coal handling capacity and other industrial developments such as aluminium smelting.

The port growth is one among up to 11 port developments planned for the Queensland coast to cope with the massive increases in output due in the next decades. But plans have caused major controversy around environmental fears for the Great Barrier Reef and

the world heritage national park that surrounds it, since most of the ports and the shipping movements to service them, would be inside its boundaries.

The mining industry and Queensland government claim the fears are overstated and that evidence from Gladstone's ongoing development indicates little impact on the reef and its environment. But it is not an issue that is going to disappear.

Other gas production is also underway from shale deposits in the south-west of the state, more akin to the fracking in the US and even Britain.

"We also have oil production from shale," says Roche, "which is not an underground methodology but the surface excavation of oil shale sands which are then processed to remove the oil."

This is more akin to the shale extraction used in northern Alberta, Canada. Much now hinges of the rest of the world and the economic developments in the next period.

WESTERN AUSTRALIA

If Queensland is a huge area then Western Australia is a sprawling giant occupying 2.5km², one third of the whole continent. The population however is just 11 per cent at 2.4 million, nearly 80 per cent of them in the south-west corner around the capital, Perth.

The vast spaces contain even more in the way of mineral and energy resources than the rest of Australia and the mining activity to extract them has been the engine of the Australian economy in the last decade particularly. In 2011 sales were a record AUD 108bn (USD 102bn). This dropped back to AUD 97bn (USD 92bn) in 2012 as major customers like China's fast expanding industrial sector slowed down, and India as well. Japan is another major customer.

The picture this year is more uncertain as the global economic crisis continues to make itself felt. Even so overall the state economy grew 6.7 per cent in 2011-2012 to AUD 239bn (USD 226bn), "primarily due to an intense investment phase in iron ore and LNG," says Colin Barnett, the state premier, in the latest *Prospect* magazine issued by the DMP.

It is iron that makes the biggest contribution to the mining economy, accounting for AUD 51bn (USD 48bn) last year, around 70 per cent of total mineral sales. This was a drop of 19 per cent on the previous year largely caused by a major fallback in prices; physically, output increased 12 per cent to 476Mt.

> "The fly-in, fly-out workforce does not build the social connections locally"

Most of this comes from the giant open cast mines of the Pilbara area, where huge semi-automated mine operations carve their way through mountains of ore. Deposits are estimated at around 26,000Mt. Drilling and transport is increasingly done by remote operations, some from Perth by satellite telemetry, and even the long ore trains on the purpose-built railways to the coast are automated and sometimes driverless.

But a huge workforce is still required for many operations like loading and trucking, which uses some of the biggest excavators and trucks in the world, such as the 363t capacity Caterpillar 797F. They are loaded with excavators like the Terex RH400, with a 50m³ capacity and the 40m³ Hitachi EX8000-6 and Liebherr R9800. Komatsu also makes a giant PC8000-6. Drilling and blasting execavation also needs a workforce still for many operations.

The highly paid miners mostly work on a fly-in fly-out basis, arriving for one or two week shifts and leaving again. Staying in the small towns in the area is costly, with apartments fetching as much as AUD 6,000 (USD 5,686) a week. The impact is socially distorting, say many of the original residents of the small towns in the area and even Perth can feel dominated by a transient population.

The Pilbara is one of nine regions in the huge state, which has one of the most varied and important geologies in the world, with rock dating back more than 3bn years in places, and at the same time, some of the youngest too. Many of these have minerals resources from diamonds and copper in Kimberley in the north, to the gold and nickel of the Kalgoorlie Goldfields-Esperance area in the central east of the state. Oil, condensates, gas, liquefied natural gas, and LPG butanes and propanes are also found, some offshore, and provided a AUD 24bn (USD 22.8bn) contribution in exports in 2012.

"Much of the region is ancient," says GSWA's Rogerson, though of a complexity and variability that keeps an 800 strong team busy in his department.

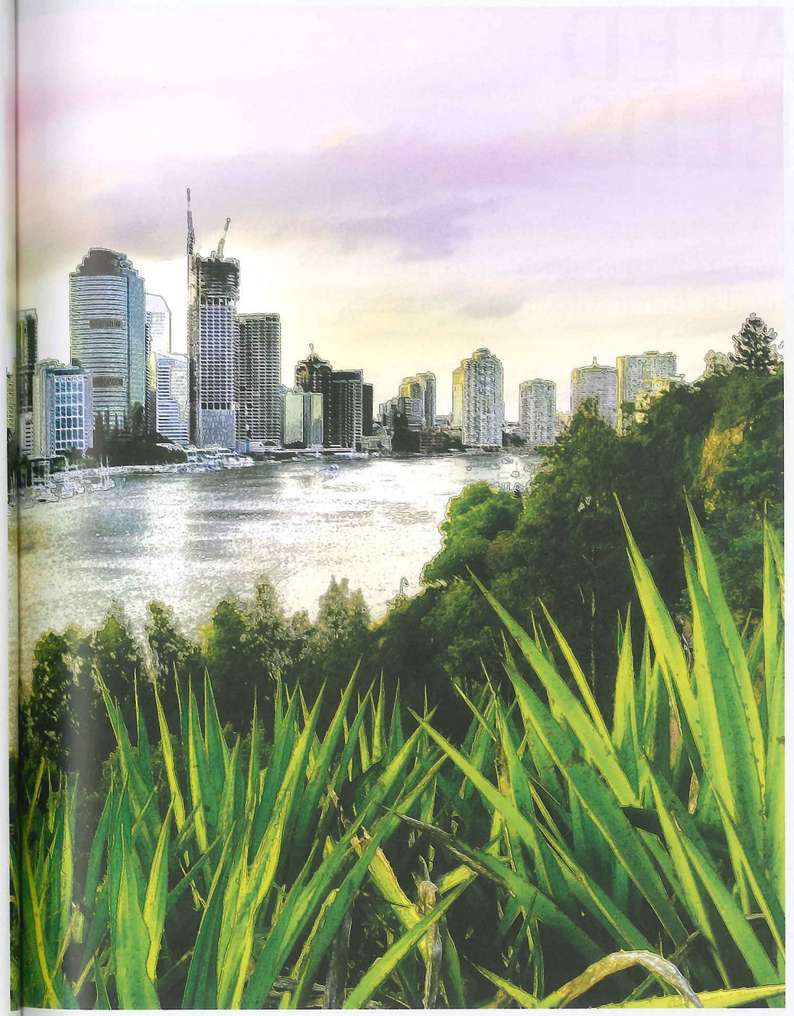
The Pilbara lies over very ancient rocks up to 3.4bn years old he says, although the richness of the iron ore deposits is due to movements and activity in a thick layer of eroded rock and soil above, a regolith that is 30-40M years old. "It transformed lower deposits of magnetite into haematite which is an ore with much higher iron content."

Another important mining area is in Goldfields-Esperance, which was once a location for a classic gold rush at the turn of the 20th century, around the town of Kalgoorlie, 600km west from Perth. Even water had to be transported there for a 100,000 population in the arid semi-desert outback, though a pipeline from Perth was eventually built that now brings a supply for a reduced modern population of 30,000.

Gold is still produced, in an area, which is about fifth in world output, notably from the giant 'Superpit' opencast mine outside the town, the world's ninth largest single mine, which is making a vast open pit down through an ants nest of tunnels from older underground workings, processing the still bearing ground from around the worked out seams.

Outside the town in the flat sparse bush landscape, dotted with salt lake pans, it is still possible to find gold nuggets loose on the ground, or just under the surface here and there even – very rarely – weighing more than 1kg.

But across the flat landscape by the long straight highways,



Above: Brisbane, capital of Queensland

there can be seen spoil mounds from open pit and sometimes associated underground mines, mostly for gold although nickel is also mined.

Gold activity in recent years has been driven by a high gold price even though costs in Western Australia higher than some of the world's gold mining regions, says Roger Pike, a spokesman for the DMP.

At USD 1,800 an ounce at peak last year it was 'irresistible' for mine companies to invest. Though it has since fallen back to around USD 1,300, this is still a high price compared to pre-credit crunch levels.

The gold ore here tends to be found in the so-called greenstone belts that pass through ancient granites dating back as much as 2.7bn to 3bn years. The belts have mixtures of rocks including sedimentary rocks like sandstone and "tend to be quite well folded," says Barnett. "The gold bearing fluids come from deep down, even close to the mantle and are forced up through major faults to points where there are structural weakness laterally. Physical and chemical changes in the rock force the gold to drop."

Mostly to date the gold is mined near the surface although deeper underground mines follow seams to about 1,000m. "There is not a special reason why they will not eventually go deeper," says Barnett, "except that it gets more difficult and expensive."

Some mines go long distances laterally, he says, under the salt lakes.

To date the mines lie in a large area around Kalgoorlie, which has become a major service community with equipment, maintenance and materials suppliers routinely driving the up to six or seven hours needed to reach them.

Recently the state government has been keen to see expansion to the east of this area, says Pike, closer to the state border. The gum tree outback gives way to even drier scrub and near desert towards the centre of the continent and so conditions are difficult. The government offers subventions for exploration activity and there have been some large discoveries. One of the biggest is the Tropicana, 330km northeast of Kalgoorlie, which begins production this year.

One of the problems of the very remote mines is that they encourage a trend already well established of complete 'self-sufficiency,' which has seen mine operators more and more using tightly-priced contract suppliers bringing materials and repairs from outside, and even directly from overseas, says Hugh Gallagher, president of the Kalgoorlie Chamber of Commerce.

"Accommodation units for example are brought in prefabricated from outside rather than using locally workshops," he explains.

This trend can damage the smaller and medium businesses locally that rely on service and supply contracts. "This business cycle we are missing some of the follow on effect that usually occurs as there is an upturn."

Without the flow of work into local business he believes the social fabric of towns like Kalgoorlie could be undermined. The boom in oil and gas in the north, and in iron, has seen towns disrupted because the bulk of the population is transient, attracted by the high wages paid by the very large mining companies. The fly-in fly-out workforce does not forge the social connections locally to build communities like Kalgoorlie and the high costs become an issue even for local cafes and supermarkets, he says. For the minute he says, the gold industry has a different character and the town is holding onto its soul. The boom times have been good and helped Australia keep afloat despite the global downturn. But the local people should not be forgotten

AUTOMATED GOLDFIELDS

Australia's deep mines have stuck to tried and tested manual drill operations until recently. But a few mines are testing out computerised rigs, a possible prelude to fuller automation. Technical journalist **Adrian Greeman** reports from one in Western Australia's Kalgoorlie region

IN LOOKING to develop a mineral prospect, a number of factors need to be determined and weighed in balance, including geology and mineralogy at the time, and ore valuation forecasts over the various horizons for possible life-time periods of the potential mine. Into the planning investigations also goes potential mining methods and sizing for mine production, the openings, productivity and costs.

The massive iron ore mines of the famous Pilbara region in Western Australia nowadays use largely automated drill rigs and driverless trucks to speed production; the ground level equivalent of 'drones', it might be said. Via GPS and satellite control systems many are remotely operated from command centres hundreds of kilometres away in the state's capital, Perth.

But the many deep metal mines found more frequently in the gold fields to the south of the state, have traditionally follow their own tried and tested ways, relying on skilled operators and manual mark-up for boring access tunnels and the production drilling of adits and stopes into the ore body.

"The tape measure and the can of spray paint is very much the usual means to mark up the face," says one local mine engineer. Anything more than that is viewed as an unnecessary expense. The economies count, particularly in small and medium size mines with constrained capital investment and requiring twisting and turning short runs of small tunnels to reach and then haul out the ore.

For boring these rough and ready mine tunnels, robustness and flexibility of machines is valued firstly. They are used as all-purpose tools, for basic drilling, anchor installation, for scaling back underbreak and cleaning. They also pin mesh to the walls and very often the tunnel face for safety. Precision needed in construction work for long life tunnels is not so important and even basic computerisation of rig is rarely used.

Adrian Greeman
Is a former editor of and long-standing regular contributor to *Tunnels*

That might be beginning to change and at least two or three mines are testing out some of the modern automated equipment to assess cost effectiveness and productivity. If the trials go well that could see much more automation within deep mines, using handheld remote controls and perhaps operation from surface control centres eventually.

One of the most significant trials is at a medium size mine in the Kalgoorlie region owned and run by the Barrick mining group. It lies about four-hours drive in the wide flung outback region around the once boom city of Kalgoorlie, a centre of a great 19th century gold rush.

The town and hinterland is still a major producer of gold and other metals like nickel and lead. Open pit mines are dotted around the flat open scrubland, and many of these have associated deep mine works which continue extraction further downwards with deep mine methods.

The Granny Smith mine is currently trying out a newer machine in an underground mine extending extraction onwards from the bottom of one of its several open cut pits. An unusual shape to the mine's ore body has made it particularly suitable for testing out a drilling jumbo from Atlas Copco fitted with a

Opposite: There is less reliance on visual targetting by operators

Below: Automation is becoming a key feature for drill rigs in some mines

Granny Smith

The Granny Smith mine is fairly representative of the pits and mines in the Kalgoorlie area, covering an overall claim area perhaps 20-30km long. Within that a series of several extraction pits service a central leaching and processing plant where a standard carbon-in-pulp plant is used to extract the gold from a cyanide leachate produced from the crushed ore.

The mine is self-sufficient in power generation and brings in the resources it needs in materials and supplies by the big three wagon land trains that are a distinctive feature of the Western Australian highways. The workforce stays on site in dormitories, with a fortnightly shift pattern.

At the mine itself the ore is brought to surface in 60t Atlas trucks loaded at the face using Caterpillar machines says mine manager Andrew Cooper, both makes being the most reliable for the purpose he thinks.

Delivery from a stockpile outside the mine portal in the base of the old open pit is done by a specialist mine trucking subcontractor hauling it to the process plant about 10km away; like many of the mining companies Barrick sticks very much to its core business says Cooper and peripheral work is subcontracted.

For the same reason it employs a specialist geotechnical consultancy to carry out the continuous forward probing and ore body mapping needed to establish the precise location of the useful ore. Some mines also use a separate subcontractor for the development tunnel work though at Granny Smith Barrick is handling this directly.

The working life of the deep mine is expected to be another eight years or so on a mine that was expected to last around three years when it started in 2006. "We have extended it year by year as the core drilling has progressed and found new reserves" says Cooper. Ore quality is a medium grade of approximately 5.5g/tonne and despite a relatively high cost of extraction this is very worthwhile with recent high gold prices.

rig control system (RCS).

Unlike the majority of the mines in the Kalgoorlie area, which often have rich but narrow vertical seams chased with spiralling ramps from level to level, the Granny Smith has big flat ore bodies, explains Kim Gunderson a production engineer at the mine.

"The geological formation seems to have seen an upwelling into ground with relatively porous lenses of rock every 120m or so," he says. "That leaves us with quite large bodies of ore about 6m to 7m deep and quite long.

"Most mines would use fairly short drives to the ore and then push out quite long production holes to extract the ore itself," he explains. But the Granny Smith requires much more "development" work, the miners' shorthand for the slightly larger tunnels used to get into the ground and access the ore in the first place.

"We drive maybe 1,200m of development a month and then relatively short production tunnels. Other mines might do 200m only of development drives."

The necessity for longer tunnels made it worthwhile to see if the mine could improve drilling efficiency, he says, and would give an RCS rig a chance to show its benefits. These include savings and efficiencies in the drilling work. The on board computers, which direct the booms and drilling operations, positioning the booms accurately for the drill pattern and then operating the drilling. The machine is able to control its movements and drill rates in an optimised manner for the engine, the hydraulics and the bearings, which reduces wear and increases accuracy. It also uses the most efficient path from drill hole to drill hole to minimise movements.

But the computer control was only a secondary reason for selecting the rig, an Atlas Copco two-boom M2C .

The primary concern was to use a rig with longer drill mountings allowing it to drive deeper rounds for blasting, says Andrew Cooper, the mine manager is charge of operations overall at Granny Smith.

4.6m
Depth on average of the drilling rounds on the two-boom Atlas Copco M2C

3
Cycles rather than four or five to blast the tunnel makes for significant time savings

"We are using a long feed mount for the drills on these booms, which allow drilling rounds up to 4.6m deep on average," he says.

This configuration is different to the three other twin boom tunnelling rigs used on Granny Smith and in fact those used in most other mines.

"Normally we use a split feed," explains Gunderson, who has been working closely with the machine. The telescopic mount of a split feed allows it to be shorter when withdrawn, he says, which gives a machine flexibility in the relatively small diameter tunnels used in the mines.

Development tunnels are usually 4.6m square for the ore drives and 5.2m by 5.7m for the main haul and access tunnels for the trucks.

With the split feed, booms can be turned and angled in all directions, allowing installation of anchors into the tunnel roof and change of direction when using the rigs for scaling work. Skilled operators can twist and turn the booms rapidly as they chip away at protrusions.

The long feed mounts on the new rig are better suited to making long straight drives. Allowing for longer blast rounds can reduce the number of cycles needed to blast and excavate the tunnels.

Three cycles can replace four or five, which gives significant time savings, particularly for loading, and for installing the necessary support. Combined with the enhanced accuracy of the RCS this adds up significantly.

"There is less set-up time overall and less travel time for the rig. It adds up over time to a lot of material we don't have to move about in the mine or dispose of outside," says Cooper

"We drive maybe 1,200m of development a month and then short production tunnels"

"especially on longer development drives." That counts on the Granny Smith's very particular ore deposits.

Once the long-feed was chosen it then made sense to chose an RCS rig since with a longer bore, reducing deviation during drilling would have a bigger impact than with shorter drill holes. Keeping overbreak to a minimum on drives is more easily achievable with the computerised controls.

Cooper says, an eight per cent gain has been made, though on some rounds a 50 per cent reduction is achieved, which implies a better performance will come with experience.

Atlas Copco itself has been to see the rig tested, too, and offered the mine a full backup and training, according to local manager Dave White at the company's Kalgoorlie supply and maintenance base.

The company already has a good working relationship with the Granny Smith mine, which uses a significant range of Atlas Copco equipment including five of its well regarded 60t MT6020 mine haul trucks as well as the other twin-boom jumbos, another Boomer M2C and two Boomer M2D machines, all manually operated. Long bore Simba drills, also from Atlas are used for extracting the ore itself.

In its overall look and feel the new RCS rig is similar to an existing hydraulic control rig. The difference with the new machine is the on board computers that direct the booms and drilling operations, positioning the booms accurately for the drill pattern and then operating the drilling, he says.

Drilling patterns are not marked up by hand but calculated above ground by a mine engineer, using the survey and core drill data from the geophysicists, which is constantly being updated, refined and extended to give the best precision possible in reaching and extracting the ore. Perhaps more than on most mines the sheer value of gold makes it important to be as precise as possible in avoiding any dilution with non-bearing or low content rock when blasting out the ore itself.

The output from the software feeds into the machine and either controls it directly or is displayed on a screen for the machine operator to follow.

The rig operators at Granny Smith declare that the machine is much easier to use and for much of the drill pattern they can usually simply load the engineer's design and go straight ahead. There is still some manual work to do since the machine does not drill the outer perimeter of the drill hole pattern. "It brings the boom close to the wall of the tunnel and there are automatic cutouts that operate," one of the operators explains.

"There are interlocks and cutouts," agrees Cooper, who has been tracking the progress of the machine carefully since it was brought into use about two years ago. "They just prevent any damage if it gets too close."

Atlas Copco is working to reduce the cutout envelope for its latest machines.

The operators seem to have embraced the new rig, reports Cooper. Overall he says the machine can help the operator achieve a good result more consistently, even when he might not be as experienced as some of the most highly skilled operators. "He is less reliant on skill and judgement and positioning the booms by eye" he says "even though he still needs to know what he is doing."

That means there is potential to keep production going even when there is a shortage of the most highly-skilled rig operators, which in the current high levels of output in Western Australia, is a major issue. Labour and especially skilled workers are at a premium, and wages high, for both iron and high value metal mines.

There are some counterpoints, however, says Cooper. The machine needs to be backed up with one of the other drills for mesh and scaling, though admittedly there is less of that to do. The ground is relatively good, too, he says, which means there is less anchoring and support needed than might be the case elsewhere.

That perhaps means a smaller mine might have second thoughts, though his has enough work going on to be able to shift the machines easily from section to section and make good use of them.

Granny Smith mine is still reviewing its assessment of the rig at present, says Cooper. The decision to use it put Barrick out on a limb in the Australian industry, which has been biding its time on these advances.

"Being first is never easy," says Cooper, though he says the decision to try the machine was carefully thought through in consultation with senior management.

But the continuing improvements needed in safety in mines, and the growing capacities of computers, data transmission and satellites, are factors likely to push the industry in the direction of more automation and remote control.

Atlas Copco is certainly keen to see the technology advance.

For the moment this trial is still a long way from robotic control systems like those on the big surface mines because, not least, telecommunication and radio telemetry signals cannot reach through the ground from GPS and other satellites.

But various possibilities are opening up including remote machine operation with local umbilical cables to an operator standing in a safer position along the tunnel and perhaps at the surface via the fibre optic networks increasingly installed for mine communication

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What do you think? Send your views to the editor and join the debate

Below: Rock support application

FOLLOW THE SEAM

A mine complex close to Kalgoorlie includes deep mine extraction chasing narrow seams deeper into the ground. Technical journalist **Adrian Greeman** reports

A MAJOR MINE project just half an hour by 4x4 from Kalgoorlie township – "practically on the doorstep" as one local supplier put it - is typical of the extraction projects in the Western Australian goldfields. An assortment of small and medium open pit excavations over a 30km wide area provide the bulk of the ore for a central processing plant close to the highway northwards, supplemented with a higher grade ore from deep mining.

The underground operations at the mine follow various small, narrow seams of glittering white gold bearing quartz deeper than the 100m depth of the now worked open cut pit where work began.

As with many of the underground mines in the region, these are nearly vertical gold seams running perhaps up to 1,000m deep. They are particularly rich in gold content, closer perhaps to the original gold rush ore extracted at the turn of the 20th century in a tunnels deep below Kalgoorlie.

"The average grade from the open cut here is about 7g/t," explains the underground mine superintendent for the deep mine work.

"The richer grade from the underground seams is used as a sweetener. "We get up to 32g/t from seams like these," he says.

The additional rich ore is mixed in with the open cut ore in carefully calculated quantities, and this helps the engineers keep the gold content content in the crushed feed slurry at the optimum levels needed for the post-processing at the separation mill and afterwards.

7
Grams per tonne is the average grade from the open cut in the vertical seams

450m
Current depth for mine workings with more to go

The mine uses the common carbon-in-pulp separation system with activated carbon binding to gold dissolved in a cyanide solution.

At Paddington there are three vertical seams that are being mined all at once, two essentially vertical, the superintendent says. "The other is slightly dipping but not much."

Ore seams run through fairly solid basalt and also porphyry, says the mine's alternate manager, "though at the lower levels and you don't see it too much." Ground conditions are good, he says, and there are not really any issues with the rock bursts that can make life fraught on some mines in basalt zones. Two of the seams are fairly similar and quite continuous with only the third showing any inconsistencies. Some faulting makes it "a bit choppy," he says. "They run roughly north-south."

Reaching the ore bodies has, unusually, been done with a straight development tunnel about 1.5km long extending from a portal at the bottom of a now worked out pit in the mine, which is roughly 100m deep. The mine workings currently are about 450m below surface and could go a lot deeper yet.

"We keep finding new potential," he says. "Originally it was thought there might be three of four years of life in it but as we go we keep discovering new potential. It looks like there could be additional mine life of three to four years at present and possibly more if we keep going down. No one knows where the bottom is."

Despite potentially deeper work the mine is not particularly hot, says the superintendent, and higher velocities of ventilation have not been needed in order to maintain relatively comfortable temperatures, if a mine can ever quite be called 'comfortable'. Neither is humidity a great issue in so far relatively dry ground.

"We don't get much over 25 degrees wetbulb, whereas many mines will get to over 30 degrees wetbulb."

For much of the development drive work, which started in 2009 the mine uses a variety of maker's rigs for both drilling the blast pattern and then subsequent scaling and rock anchoring work. The tunnels, and the rock face are shotcreted and meshed, using the jumbos to rock pin the mesh in case of rock falls, and bursts.

Tamrock machines, nowadays Sandvik, are the most favoured for their robustness and simplicity, though some mines use the relatively newly arrived Atlas Copco equipment.

Adrian Greeman
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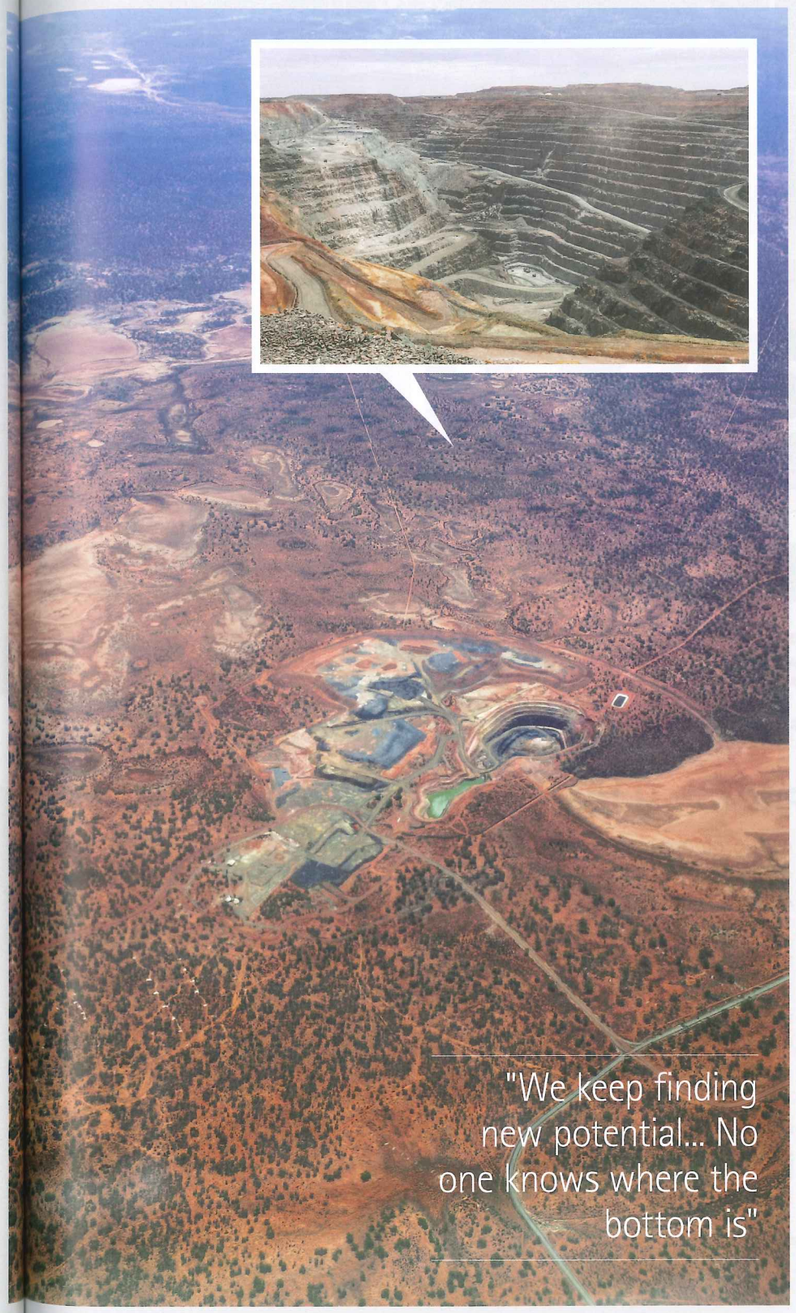


"We keep finding new potential... No one knows where the bottom is"

At this mine there are mainly Sandvik two boom jumbos with a a single boom Atlas among the other equipment, the latter used for the development tunnels and spiralling ramps which form the mining area at the end of the long access tunnel.

From these ramps drives are made north and south approximately every 10m vertically into the line of the ore bodies. From the level above the roughly 1m thick seams are carefully drilled down through the floor to produce stopes for the pulling out the ore itself.

Above: Mining near Kalgoorlie township in western Australia

The stopes are therefore about 10m deep. "We do them in 4m long panels and then backfill with lean mix concrete before moving on to the next," says the superintendent.

Mine spoil is stored in various locations in the tunnels and reused for the backfill.

"We have 'squirrel holes' and stockpiles allover," he says.

For the stopeing work the mine uses an Atlas Copco Simba S7D. The unit drives a single rod between 75mm to 150mm diameter and can drive up to 51m. The Simba is valued for its accuracy, which allows the precise shape of the seam to be isolated when drilling the stope for blasting.

"The most important part is drilling straight and making sure the holes are in the right spot," says the superintendent.

In that way as much non-bearing rock as possible can be excluded from the blasted volume while making sure to get every precious gram of the glittering white seam rock.

Dilution is an important issue in keeping costs down, particularly for gold where a tonne of crushed rock has only a few grammes of the metal in it.

In fact a team of geologists and surveyors is constantly at work in the mine taking cores to give a running check of the ore content, its precise position and where it seems to be running on.

When the stopeing blast is done, ore is loaded from the lower access using Caterpillar loaders and dumper trucks. These are considered the best option at present though the mine, like many in Australia is considering the the Atlas MT42 trucks and has done some trials.

The work is continuous with approximately 14 on each crew of miners and maintenance crews. The four crews between them work around the clock with a pattern of seven days on and seven days off back to back.

"Its actually a very good mine to work in," he says. The company, "buses the guys in and out," and it gives good benefits he says including medical costs.

"Actually it places an emphasis on work life balance, something made easier by the proximity of the town, so that there is not the same need for remote living in camp and fly-in and fly-out scheduling as there is on many of the mines. It means the workforce is pretty stable. Normally you would have 30 per cent plus churn in the overall workforce but it's much less here."

With at least another three years of mining to do that will prove useful

INFRASTRUCTURE EXPANSION

Mining developments in Queensland require major port expansion. One of the largest schemes is underway at Gladstone. Technical journalist **Adrian Greeman** reports

CONTINUING AND even accelerated expansion of mining and mineral resource development in Queensland, Australia, demands significant new transport capacity, not least because the greatest proportion is for export.

Some 11 possible schemes for new or expanded ports could go ahead in the coming period. These are not without significant controversy, particularly from the environmental impact they could have, most of all within the area of the Great Barrier Reef, a world heritage protected area.

One of the biggest schemes currently in progress is a major expansion of the Gladstone harbour, sited at the mid-point of the Queensland coast, about 520km north of Brisbane. "This is a natural deep water harbour that has been under development since the 1960s," says the former chief executive of Gladstone Ports Corporation Leo Zussino, who has overseen the port developments for some 20 years. He was recently replaced in the role by Craig Brody.

In past decades the tiny, 3,000 population harbour has grown into an 63,000 population industrial port, with aluminium smelting facilities, serviced by a major coal fired power station, and coal handling for export of the coking coal produced in Queensland's Bowen. But it is now jumping to a new level. Major development has been underway since 2010 with the expansion of an area north of the main town, predominantly offshore on the large Curtis Island. Here three LNG projects are under construction by Britain's BG Group, and two Australian firms, Santos and Origin Energy.

Each scheme costs in the region of AUD 18bn (USD 17bn) and comprises liquefaction processing, and massive storage facilities at the harbour as well as the networks of pipelines and extraction wells to underground coal seam gas extraction in Queensland's interior more than 400km away. They are due to come on stream between 2014 and 2016.

A fourth scheme is now under construction, and may be joined by a fifth under consideration. Even without the final scheme the facilities will put Gladstone alongside Qatar as the world's natural natural gas exporter, says Zussino. The Curtis Island development is part of a 28,000ha (280Mm^2) state industrial development zone, which also includes Wiggins Island where existing coal handling terminals are being expanded. A new terminal at Golding Point will double capacity there, and another expansion is doubling the capacity of the port's RG Tanna terminal. Coal arrives by rail.

"We have an additional 60Mt of coal export at the beginning with capacity to reach 150Mt," says Zussino.

To service the larger ships that will carry these bulk energy exports the port embarked on a huge dredging programme in May 2011 to deepen existing ship channels and create new ones, as well as 'swing basins' for ship turning. The project removes some 26Mm^3 of material to allow for 13m draft ships to the LNG terminals. For the coal terminals another 20Mm^3 could also be dredged.

28
Thousand hectares has been zoned for state industrial development

300
Million tonnes will evenutally be the harbour's annual capacity

Disposal of the material has mainly been at a coastal site being used for a 274ha reclamation north of a point known as Fisherman's Landing where 17Mm^3 has been deposited within a retention bund, and the remainder will be placed as the project reaches completion this year. Another 4Mm^3 has been dumped at a designated disposal site offshore.

Both the port expansion and the dredging work have been controversial because of the proximity of the Great Barrier Reef, a highly sensitive marine environment and a UNESCO world heritage area. Environmental objectors say that turbidity and heavy metal suspensions have damaged wildlife and are concerned about the large number of ship movements that must pass through a channel in the reef in order to access the harbour.

Gladstone Port and the Queensland government counter that the project has been carefully monitored. They point to heavy flooding two years ago and the substantial runoff it caused as being responsible for some observed damage and diseases in fish populations.

One final issue for the port, says Zussino, is that it does not oversell its capacity. Ship movements have to be carefully planned especially as it expands, to prevent clashes.

"We spent three years with consultant Maunsell developing a very sophisticated channel model to assess the impact of any new industrial development and the effect on current wharfage" he says. "It is the best AUD 10M [USD 9.5M] we have spent."

The model will help long term planning, Zussino says, which will see the harbour reach a possible 300Mt annual capacity eventually

Adrian Greeman
Is a former editor of and long-standing regular contributor to *Tunnels*

INROADS BELOW

TBMs, hybrids, and pipejacking technology are finding greater applications and opportunities in mining, reports **Patrick Reynolds**

IN FOLLOWING where the strata, seams or ore bodies (reefs) lead in underground mining, great service has been brought by – and continues to come from – the long proven methods of drill and blast along with other mechanised excavation, such as using roadheaders, raise bores and also hand digging. All are able to virtually turn on a dime below ground, which is vital as the ground is read for commercial opportunity and also risk.

Patrick Reynolds
Patrick is a freelance technical journalist who has covered tunnelling projects worldwide and has a mining background

The expanding ranges of offerings to the mining sector include: Sandvik's DS421 cable-bolting rig for small tunnels, its new range of UDR exploration drill rigs, and the bolter miner MB610; Atlas Copco's recently launched range of four new Simba rigs for long hole drilling and the Boomer E1 C-DH for sites lacking water and electrical infrastructure – all of which follow the previously introducing the Boomer T1 D for narrow vein mining and the M1 L rig for low vein mining; and, from Aker Wirth, came the T1.14 roadheader which is compact and has been optimised for coal mining.

However, while not newcomers to the sector, and despite the challenge they have of typically taking much longer distances to make turns causing them not to have been seen as the ubiqitous choice for excavation in mines, there are new opportunities – and demands – for TBMs, or variations on them. TBMs are increasingly finding their place in the sector.

TBMS

A plus in the favour of TBMs is their ability to produce faster advance rates and for lower operating costs than traditional methods, although on the downside they cost more to acquire, – historically, about 1.5 times the capital spend, according to Stillwater Mining Co.

However, TBMs usually take longer to set up before production gets going and, depending on their size, can have far less local flexibility when underway compared to the other excavation methods, as noted. The shields can have the likes of a 300m turning radius compared to often 20m in conventional mining, though towards the latter scale are coming hybrid machines, such as Aker Wirth's new mobile miner system.

But if long access tunnels – particularly those that are slight, gradual or have few deviations in alignment – are part of a mine's development plan then the issue of the turning radius is not so much of an issue.

Mike Koski, the chief geologist at Stillwater Mine in Montana notes that the degree of manoeuvrability needed is dependent on what lies underground, such as the reef geometry, and also the access needs.

A further variation in reflecting upon the options comes with the support required for mining – physical support to help maintain structural integrity of excavations as well as all the other types of support systems and methods to ensure safety. For a given set of geological conditions the mining work, performed by different excavation methods would, most likely, call for varying degrees and types of ground support; in terms of further aspects of safety, the other support choices are around factors such as ventilation, air quality, vehicle movement, personnel evacuation from a blast area shutdown, etc, which all feed in to mine development as well as operations.

The merits of different excavation methods and typical support required depend, like with civil engineering to some degree, on the nature and scale of the objectives developing the mine and weighing the long-term economics of alternative choices. Unlike civils, however, the nature of mining would see the excavation assets working as part of the operational phase of the site; they would be there not simply as part of the set-up stage but for the longer-term, which further influences economic choices.

Robbins at Stillwater

The Stillwater mine is among the leaders in use of TBMs in mining, but the site also continues to employ a range of excavation methods, notably drill and blast (jumbos, down hole drills, and raise bores). In the third quarter of this year, the mine owner, Stillwater Mining Co, was getting underway the fourth TBM it has deployed during the life of the mine, which extracts platinum and palladium from a major reef.

Above: Sandvik Bolter Miner MB610

Opposite: Access tunnel bored by Seli Compact DSU at the Los Bronces mine in Chile

The shield – a 5.5m Robbins Main Beam TBM – was not built originally for the mining task but is crossing over from civils works performed on the opposite side of the US. The shield was among the handful of TBMs on the intricate rail tunnel excavations below the heart of the Big Apple, where multiple parallel and branching tunnels were opened up as part of the complex East Side Access (ESA) project.

Following a complete refurbishment, the TBM will bore the 'Blitz' tunnel which will open up access on the east side of the mine. The initial plan is for a 7.1km drive and five major faults are anticipated. The cutterhead is equipped with 25 x 19in single discs plus 4 x 17in center discs, and has rated thrust of 10,898kN, rated power of 1,968kW (6 x 328kW), and torque of 2,630kNm at 7.2rpm.

While the shield gets ready to bore on the Blitz, another Robbins TBM has been extending its mining activities at Stillwater by opening up another, 2.6km long, development tunnel for the mine complex.

When it finishes its latest drive in 2013, the additional stretch of bored tunnel will be only a quarter of the total distance excavated by the machine at the mine. The shield was previously used at the Magma Copper Mine, in Arizona.

Although they are commonly viewed in the industry as 'large and unwieldy' machines, says Tyler Luxner, a project engineer with the mining company, TBMs have been used at Stillwater for almost quarter of a century.

Stillwater's first TBM was a 4m diameter Kelly-type shield in the late 1980s. The mining company also acquired a 4.6m diameter CTS TBM in the late 1990s.

Seli's takes Compact south

In Chile, one of Seli's versatile, recent-concept TBMs was made to order to help open further, underground, sections of the Los Bronces copper and molybdenum mine.

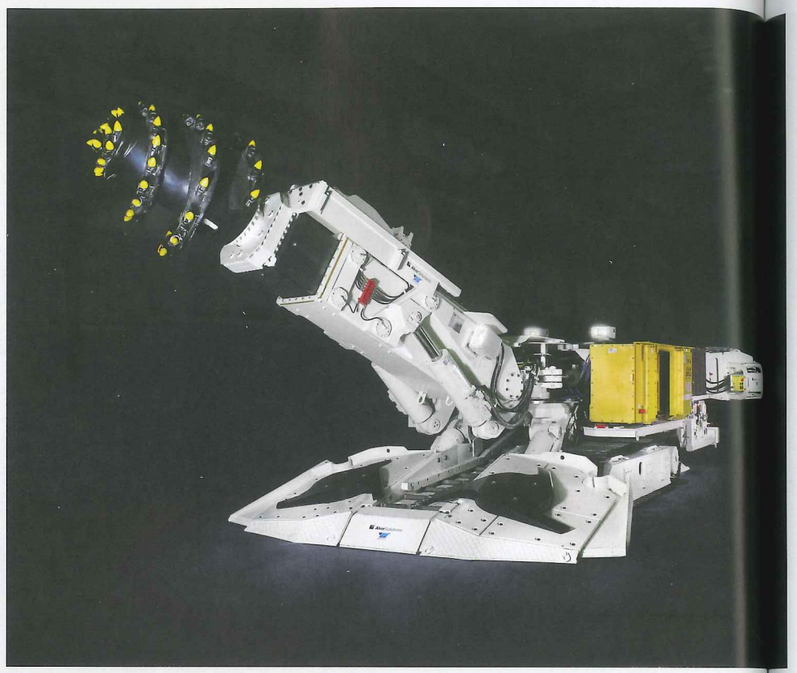
Mine owner Anglo American Chile wanted to optimise the development of the world-class Los Sulfatos copper prospect, and as customer it opted for one of the Italian tunnelling machine manufacturer's 'Compact DSU' type shields – and only the second ever made.

Launched in 2009 at the mine, some 65km north east of Santiago, the 4.5m diameter TBM was used by the mine owner's JV contractor, Dragados-Belsaco to bore the 8.1km exploratory and access tunnel. The mine until then had been an open pit and Anglo American Chile was starting to take the operation underground in the Andes mountains but space for portals was tight, which influenced the choice of TBM.

The Compact DSU is a simpler, shorter TBM meant to give the advantages of a double shield (DSU = double shield unit) while being less expensive, and it has a bolted assembly. The concept was developed to be an alternative to open shields and compete with drill and blast drives opening up headings and benches.

Another key feature of the Compact DSU system is the capability of handling a wide variety of ground conditions requiring support ranging from rock bolts, steel sets, mesh and shotcrete to steel ring erection. At Los Bronces, the cutterhead was fitted with 27 no. 19in discs, had power of 1,575kW and torque of 2,612kNm. The maximum main thrust was 15,700kN with auxiliary thrust of 14,300kN. The mine owner's contract with Seli also included provision of backup equiment, technical assistance and specialised workers.

Very early in the drive the tunnellers met collpasing faces and foam injection helped to fill the cavity and stabilise conditions. A number of fault zones were crossed, and the mine owner shifted the tunnel alignment to have greater overburden. However, more problems were met with heavy groundwater inflows of more than 100 litres per second at the face and carrying much debris. Inflows were met at other sections, some more – up to 150 litres per second – and others less severe.



Above: Aker-Wirth's new T1.14 roadheader

Opposite: Atlas Copco Mobile Miner

After just over two years of tunnelling, the TBM completed the tunnel in November 2011 and its average daily progress rate was approximately 16.5m, Seli says. The advance rates peaked at 46m/day earlier that year.

Not developed as a dedicated concept machine for the mining sector, the first use of a Compact DSU was in the civil engineering sector, on an Italian hydropower project.

> "The nature of mining is such that excavation forms part of the operation of the project"

Aker Wirth goes mobile

At another copper mine – this time in Australia, and owned jointly by Rio Tinto and Sumitomo – verification trials are getting underway with a new hybrid TBM for mines, or Mobile Tunnel Miner (MTM), made by Aker Wirth. Developed in cooperation with Rio Tinto and unveiled mid-year, tests of the MTM at Northparkes mine are the first application of the tunnel boring system.

Looking like a cross between slim, spindly fixed arms of a roadheader with the partial shield-roof and long train body of a TBM, the MTM was developed by Aker Wirth as part of Rio Tinto's 'Mine of the Future' programme, launched almost five years ago. Aker Wirth began working with the mining giant under a technological agreement in 2010.

Aker Wirth notes that development the new concept machine, which 'combines the flexibility of a roadheader with the robustness of a tunnel boring machine', builds upon an earlier version produced in the early 1990s. The manufacturer further notes that among the points of versatility, the MTM can bore circular tunnels – like a classic TBM – but also tunnels with rectangular and horseshoe-shape cross sections up to 6m wide. The company says this flexibility means 'eliminating the need to backfill the lower section of the round cross section'.

Additionally, using undercutting technology, the firm says, the MTM is 'especially efficient' in boring through extremely hard rock, up to 300MPa. The MTM is, though, also equipped with ground support systems.

The MTM also has been designed to have a turning circle of barely 30m, which near that of conventional mining equipment but allows far, far tighter turns than the usual TBMs. A number of swivel joints are used to achieve such manoeuverability for a machine of that size and capacity.

In a statement, Aker Wirth's chief execiutive Einar Bronland said: "We will revolutionalise safety and efficiency in underground mining with the new Mobile Tunnel Miner. With this tunnel boring system Aker Wirth will play a decisive role in shaping the future of the mining industry."

The first MTM was despatched in late June from Aker Wirth's production facility near Dusseldorf, Germany, to be transported to Northparkes mine for verification tests in the field. Previously, the mining company noted that the trial phase had been integrated into a pre-feasibility expansion at the mine.

Contrasting drill and blast against a fresh approach with tunnel boring systems, Rio Tinto notes the MTM should double the daily advance rate to 10m-14m/day as well as cause less damage to rock mass. It adds, though, that drill and blast has long established predigree, boasting high flexibily, scalability, and wide choice of drill and blast equipment whereas tunnel boring systems, like MTM, have been prototypes only.

It adds that such tunnel boring systems have 'an immediate application in main access development and material handling system development'.

John McGagh, Rio Tinto's head of innovation, says, "The system incorporates continuous mechanical rock excavation that will not damage new tunnel walls, while still providing the ability to mechanically install ground support in parallel with tunnel advance."

He adds: "Importantly for Rio Tinto, it provides an opportunity to introduce fundamentally safer process into the underground mining industry."

Atlas Copco, Herrenknecht

Further developments in excavation systems for mine development have been taking place under Rio Tinto's 'Mine of the Future' initiative, including technological agreements with other manufacturers, such as Atlas Copco and Herrenknecht. The former has been developing a new tunnelling machine – the Modular Mining Machine (MMM) – while Herrenknecht is focued on a single shaft construction system that covers many tasks previously done separately.

Atlas Copco's MMM builds upon its previous Robbins Mobile Miner developments and is married to long experience of other rock mining methods since the 1980s-90s. Like the earlier mobile miners, the MMM has a large diameter, forward-rotating cutting wheel but the drum is much thicker than before. The backup body is also a very different configuration.

The MMM system is getting close to trials in the field. In recent presentations, Rio Tinto has indicated that trials are proposed over 2013-14 at its Kennecott copper mine, in Utah. As required by the mining giant, the performance criteria for the MMM is akin to that of Aker Wirth's MTM in that these two tunnel boring systems are to achieve daily rates of about double that of conventional methods, such as drill and blast.

With cross-sector adaptation and leverage of technology part of its strategy, Herrenknecht has been building upon its mechanised tunnelling pedigree to take ever longer strides into the mining sector with a particular focus on shafts. It notes that with raw material deposits being exploited at depths of down to 2,000m, the need for fast and efficient exploration methods is of increasing importance especially with conventional approaches to developing the necessary infrastructures being time-consuming.

To that end, the manufacturer provides mechanised boring with various types of equipment for varied purposes, such as constructing deep vertical shafts for hard rock or weaker ground conditions, or new or linking shafts (vertical or inclined) within mine developments. In particular, the equipment types are: shaft boring machines and roadheaders; vertical shaft sinking machines; raise boring rigs; boxhole boring machines; and, shaft

sinking jumbos.

Following tests in Germany, at the Clara mine, Herrenknecht's Boxhole Boring Machine (BBM) is now in service at Newcrest Mining Ltd's Cadia East copper and gold mine in New South Wales, Australia. In developing the BBM, Herrenknecht took its experience in microtunnelling pipe jacking technology from the surface civils projects to bore a variety of vertical and inclined narrow shafts underground. The machine is used to prepare the draw points for ore extraction in block cave mining.

It is transported on a purpose-built small crawler to the tight location, placed upright, the jacking frame adjusted and braced, and the cutterhead begins boring with thrust pipes being added. The equipment is remote-controlled, does not require the crawler with the cable drum to be immediately adjacent. At Cadia East, working on site since late 2011, the BBM was used by Mancala Pty to bore more than 40 slot holes,

Rio Tinto and Copper processing

Perhaps when it comes to ground support the mining industry and tunnelling part of the civil engineering sector have one of their greatest crossovers – except, that is, for the infrequent though not unnown use of built ring lining (steel or precast concrete) in mines.

Rock strength in mines, and major civils projects in remote areas, can vary widely. Depending on local conditions, they can call for many types of ground support methods, such as: split sets, rebar rock bolts, cable bolts, plates, steel mats (bolting straps), 'mini-mats', expanded steel mesh, wire mesh, ring beams, and shotcrete.

Stillwater

Stillwater mine has geology comprising layered bands of norite, gabbro and anorthosite, and the latter is where the ore body is found, primarily. Rock strength in the mine ranges widely, from less than 1MPa to almost 140MPa and so calls for many types of ground support depending on local conditions, such as: split sets, rebar rock bolts, cable bolts, plates, mats, expanded steel mesh, wire mesh, ring beams, and shotcrete, typically applied in 80mm-100mm thick layers.

In looking to use a TBM at the mine, among the anticipated benefits was that circular tunnels would mean less ground support would be needed.

"I think our early estimations were spot on – the ground doesn't needed to be supported nearly as much. For long chunks of footwall lateral, it's a good way to go," says Mike Koski, the mine's chief geologist.

For the latest Robbins TBM to be employed at the mine, a variety of ground support methods are envisaged, and are often found also in civil projects. These range from ring beams, shotcrete, steel mesh and rock bolts to special crown support using the continuous, bolted-into-place steel fingers that come out of the advancing TBM as the core part of the McNally system.

To handle expected water ingress – historically, workings at the mine have met inflows of up to almost 1,900 litres per minute – the shield has 360-degree capability for probing and grouting. The TBM is are fitted with an erector for ring beams up to 200mm.

"Our standard ground support will be bolts with wire mesh; however, if we encounter very poor or blocky ground, we will switch to the McNally support system," says Tyler Luxner, a project engineer at the mine. He adds that they expect mainly competent rock with claylike material in fault zones.

McNally System

The McNally support system is patented by C&M McNally Engineering of Toronto, Canada, and is used on Robbins TBMs, and is licensed exclusively. It holds back weak, unstable or loose rock, forming an effective safety umbrella under which crews can work and profile integrity obtained.

The system has been employed with Robbins TBMs on a number civil engineering projects, including the Olmos Trans-Andean water tunnel in Peru, which was perhaps the most challenging so far, bored at a depth of up to 2,000m.

At Olmos, the McNally system was introduced after the 5.3m diameter Main Beam TBM encountered severe rock bursting which proved too much for the original support design that included provision for roof shield fingers, ring beams and bolting. The curved assembly pockets for the McNally system were installed on the roof of the shield, but later these were extended down the sides as part of further modifications due too more severe rock bursting. Launched in 2007 to bore just over half the length of the 20.1km tunnel, and after tough tunnelling conditions in volcanic geology where more than 16,000 rock bursting events were recorded, the TBM made a successful breakthrough at the end of 2011.

of 16.5m average length, by June this year.

Separately, in its co-operation with Rio Tinto, Herrenknecht is developing a Shaft Boring Machine (SBM) that combines three separate processes – excavation, transport and structural support, says the mining group. It adds that the SBM is for sinking large diameter shafts, and combines synchronous mechanical hard rock excavation, muck transport and rock support into an innovative single system, which is to improve construction rates and safety while reducing technical risks.

Rio Tinto is considering locations for trials of the SBM system, which are anticipated around 2015 or soon after.

Mine of the future

The agreements with three of the major underground equipment manufacturers are part of Rio Tinto's push to get at more difficult deposits and improve tunnelling efficiency, safety and economics.

The mining group is pushing on two major fronts:

- To overcome barriers to more difficult or marginal minerals recovery, such as targeting ore bodies at greater depth and overcoming declining ore grades through improvements in mining as well as processing technology;
- To achieve significant improvements in safety and speed to enable the jump in excavation volumes needed for underground development infrastructure that will be key to establishing block caving for "super mines" of inter-linked mineral deposits that are to exploited in parallel, such as the copper ore complexes of Resolution in Arizona and Oyu Tolgoi in Mongolia.

Like other excavation developments as part of the programme, Rio Tinto said all three new concepts are coming from application of civil engineering technologies crossed with its own experts' mining input as well as that of contractor partners Redpath and Cementation, respectively.

McGagh says the partnerships would 'fundamentally change the world of underground mining by further improving safety and allowing more rapid construction of new underground mines.'

He adds that the partnerships were 'valuable in helping us to solve the challenges of developing block cave mines.' Such a mining method involves a warren of tunnels below and around cone-shaped zones that will be blasted and collapse under gravity, then the rock extracted. The aim is to scale-out the sequential pattern and increase both productivity and output

Opposite, top: Atlas Copco Simba W7 C rig for long hole drilling

Opposite: Boxhole borer by Herrenknecht

GROWING UNDERGROUND

Ever more efficient mine development infrastructure, and geotechnical planning, are key to expanding production at major mines. Report by **Patrick Reynolds**

IN LOOKING to develop a mineral prospect, a number of factors need to be determined and weighed in balance, including geology and mineralogy at the time, and ore valuation forecasts over the various horizons for possible life-time periods of the potential mine. Into the planning investigations also goes potential mining methods and sizing for mine production, the openings, productivity and costs.

With respect to geology and mineralogy, key information to obtain includes: the scale of the prime and any adjacent prospects; the length, dip and maximum depth of each mineralised zone or seam, and distances to them; any known discontinuities, swelling or narrowing of the zone or seam; any sharp changes in mineral grades, and between the ore and waste, within the zone; if the ore oxidises during extraction; distribution of valuable minerals as well as those that might be harmful in mining or processing; any alteration zones.

Patrick Reynolds
Patrick is a freelance technical journalist who has covered tunnelling projects worldwide and has a mining background

Other key areas for information gathering during this site investigation work, includes: the geology and structural features of the general rock mass covering and surrounding the prime mineral prospect, including water, gases or even oil; then, more locally, the type and quality of the rock at the prospect, including strengths, weaknesses, inherent stresses, temperature, acidity, all together helping to inform the rock quality designation (RQD).

As to mining methods, the deposits can be mined by a variety of methods. Among the major mining methods are: room-and-pillar; vein; shrinkage stoping; sublevel open stoping; bighole stoping; vertical crater retreat; cut and fill stoping; longwall mining; sublevel caving; and block caving. Various tunnelling and shaft excavation methods can also be employed to get underground initially and then to advance on the deposits; to branch to new parts in the field with further prospects and then, from those adits, to excavate shafts, drifts, declines, roadways, sumps and winzes among the many other mine features.

But, from these collective points, there are key further aspects of mine planning that must be considered, including: effective understanding of induced changes through excavation and their relative size, shape and position; ground support methods and ground monitoring. Overlaying all of the factors are needs of health, safety and appropriate environmental conditions and controls.

STILLWATER PMG COMPLEX

The hot spot for platinum mining in North America is in the Beartooth Mountain Range, in Montana, at the neighbouring Stillwater and East Boulder mines, where palladium is also extracted from ever growing stretches of the 45km long ore body – the "J-M" reef. The mines are owned by Stillwater Mining Co.

The world class reef runs parallel to a river valley that is almost 50km north of Yellowstone National Park. The richness of resources along the east-west running reef gives it strategic importance in global supplies. It is one of the only significant sources of the platinum metals group outside of Russia and South Africa; the mine produces four per cent of the world's platinum supply and nine per cent of the palladium.

As development of the mine has progressed to new parts in the large reserve blocks with main access adits (footwall laterals) and so extending the life of the site, then miners have had to reach farther out into the reef for platinum, palladium and the minor amounts of rhodium available. There are also significant amounts of iron, copper and nickel, plus traces of gold and silver. The reef has been found to be highly homogeneous, and longer development bores are needed to link to, and open up, the blocks.

Stillwater Mining also operates a smelter and refinery in Montana. In recent years, production of the platinum group metals has been around half a million ounces annually, and based on historical drilling data the company has estimated there could be another 115 million ounces of undeveloped mineral resources within the area controlled by the mine.

Based on expansion plans issued in 2010-11, Stillwater Mining expects to add approximately 200,000 5,700kg ounces of platinum group metals by 2014, which would be an increase of about 40 per cent, and still mean the untapped, estimated resources would equate to 150-160 years of annual production at those higher levels of output.

Geology in the mine area comprises a layered succession of ultramafic to mafic rocks with bands of norite, gabbro and anorthosite. Crystal settling allowed the heavier mineral ore to settle to the bottom with th lighter siliceous minerals remaining near the tip. Originally horizontal, the typically long narrow

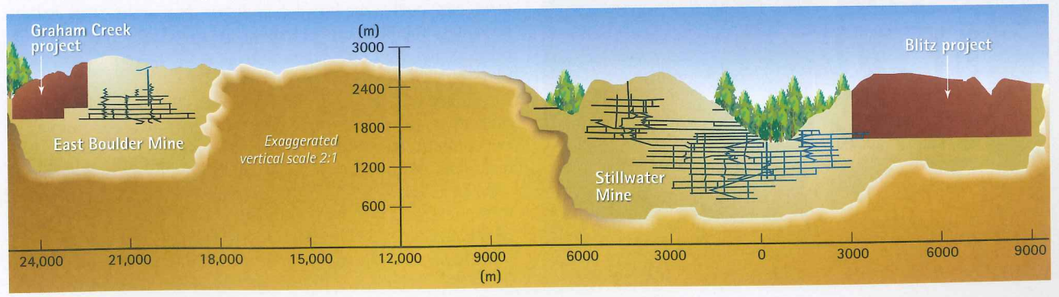
9%
Of the world's supply of palladium comes from the J-M reef.

40%
Increase in platnum group metals is expected by Stillwater Mining.

Above: An Atlas Copco Boomer for narrow vein mining

Left: An Atlas Copco M1 L rig for low vein mining.

Below: The East Boulder and Stillwater mines



reef was tilted and fractured by crustal displacements, and the platinum group minerals are found in layers averaging 2.4m thick though can be down to only 1m, approximately.

OPENING THE MINE

The J-M reef was discovered in the 1970s and production began in the mid-1980s. Progressively, the mine opened up with drill and blast drives but very soon the first TBM was in the ground, in 1988. Since then, and in addition to use of TBMs for the footwall laterals, the mine has expanded with typical drill and blast, or small boring equipment, for excavation and advancement methods such as ramp and fill, sub-level stoping and captive cut and fill.

Typically, the TBMs are used to construct the main adits and also to bore some crosscut access tunnels. In total, the three TBMs that were used – the fourth is just about to start – have bored more than 32km of tunnel, sometimes at a relatively quick pace (the Jarva shield driving 7.7km during 1991) to very slow, such as the first Robbins machine excavating 2.2km over eight years, according to the mine owner's schedule.

However, more recently, the Robbins TBM, which was the third shield on the reef, has been boring the new footwall lateral for the Graham Creek section of the reef, adjacent to East Boulder Mine. With completion of the drive expected around within six to eight months, the mine development work at Graham Creek will then switch to adding new ventilation raises and other infrastructure to allow sustainable ore production to commence. The mining company has commented that most of the development cost is on raise boring or drilling next to the TBM. However, the shield was already on site as an owned asset, or sunk cost.

For the latest Robbins TBM, the primary objective is to bore the Blitz tunnel from Stillwater Mine alongside the reef and help define what resource there is and how to approach it. The Blitz project also has another tunnel being excavated by conventional mining, and will eventually intersect a new entrance to the mine from the suface.

The TBM will bore at least 7km to help detect the edges of the reef along the eastern side of the mine. The tunnel will also be used as an access and rail haulage tunnel for the long-term. Expected to be bored over about three years, there is the possibility the Blitz tunnel may be extended, and the TBM will drive farther, but it all depends on how the quality of the reef plays out beside the initial Blitz tunnel.

Aquired and refurbished for the Blitz job, the TBM has two drills mounted for miners to consecutively probe and sample the complex mafic norite geology by diamond core drilling. The rock mass will be pierced ahead, above and to the side of the TBM at intervals of 150m, and so help to establish the edge of the reef as it is steered to transit the boundaries. The length of the drill holes is to be 182m. "We will drill and log the core right there while we are drilling it, then interpret the results, so it will be concurrent with boring," says Justus Deen, the mine's head of technical services.

With the TBM's path being adjusted less by absolute pre-planned survey control and more with adjustments to optimise its position against the perceived distance to the reef, the control is like civils in that local actions are taken to deal with geological discoveries. Unlike mining though, such as in this case, in civils the adjustments are often to put distance between the shield and zone in question, often where there is potential for problems or at least sufficiently less favourable ground, or anticipated greater risk. In mining, the shield is brought closer – but not too close – to the prize.

Platinum and palladium are in base metal sulphides, and that ore is located in a distinct layer of igneous rock – "so if we penetrate the right rock types then we know we are in the right place," says the mine's chief geologist, Mike Koski.

The metals, he adds, are typically found in only half the core samples, "so the rock types will guide us." To that end, Koski continues, "we don't want to get too far away from or too close to the ore body."

Over the initial planned length of the TBM-bored Blitz tunnel, the mining company expected to undertake almost 37km, in total, of core drilling to help locate the boundaries of the J-M reef along that section. Approximately 1.1km of core drilling, in total, is to be executed at every 150m interval.

In opening the footwall lateral parallel to the axis of the reef, the TBM drive is also, in effect, an exploratory tunnel. Yet, the planning for future exploitation of the reef goes beyond establishing its boundaries around the TBM through diamond core drilling. Conventional geotechnical probing for the TBM bore – to look for weak ground in the expected mainly competent rock with clay infill at faults and shear zones, and also dykes and water – will also help to fine-tune the geological map to nail the good spots for later breakout with the branching, side access tunnels to pierce the reef, and those to avoid.

Koski says the plan is to undertake the geotechnical probing ahead at slightly greater intervals (just over 165m) compared to the core drilling. He adds, "we will know we are placing the footwall laterals in the best possible ground."

Ore mining along footwall laterals will get underway, from the TBM tunnel, while the shield continues to advance ahead into the block. To prepare for the rapidly following active mining stage, the final rail grade with ballast, wood ties and track in the tunnel will be set behind the backup train each time core drilling is underway. Prior to the final placement, the TBM backup will have run on temporary steel sleepers from the bridge area.

NORTHPARKES COPPER MINE, AUSTRALIA

For the last few years, among those business initiatives high on the agenda for mining giant Rio Tinto has been its "Mine of the Future" initiative that it believes could cut mine development time by up to 40 per cent. Launched to boost safety, effectiveness and capabilty in finding, developing, mining and recovering copper and other ores, the initiative has also seen much R&D cooperation with some excavation equipment manufacturers.

For the development strand, tunnel boring system trials are getting underway at Northparkes, a copper mine in a volcanic belt in New South Wales, Australia. The mine is held by a Rio Tinto and Sumitomo Group JV, and the aim is to develop future block cave mines in safer, faster and better ways.

Block cave mining involves undercutting the ore zone to allow collapses under gravity into ecavated, cone-shaped funnels for collection and transport to the surface. It is a mass mining method, and, says Rio Tinto, can be intensely automated and is the lowest cost underground mining method.

The first important mineral discovery at Northparkes was in the 1970s and the ore deposits are typical copper-gold porphyry system. Mine development took off in the early 1990s with open pits and, later, block cave mining – Australia's first use of the method.

The initial mine in the E26 mineralisation zone, the first to be exploited, was E26 Lift 1, which was developed in 1995. It quickly ramped up to become the world's most productive underground hard rock mine, reaching 42,600t of ore per underground employee (including contractors), according to Rio Tinto. Annual productivity peaked in 2000 at more than 50,000t per employee.

Open cut mining resumed for a few years and also some small underground works (pilar-wrecking, slots below Lift 1 extraction level) were undertaken to bridge output during the establishment of E26 Lift 2 block cave mine, starting in 2001. The Lift 2 mine was commissioned in 2004 and extended four years later. Meanwhile, construction of the third major block cave mine, E48 Lift 1 got under way and is now in full production. The E48 zone is expected to last another 12 years.

Work is now advancing on the

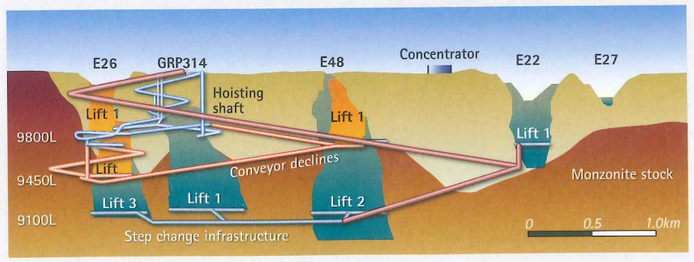
150m
Intervals at which crews will execute core drilling

32km
Of tunnels have been execavated by TBM at the J-M reef

Opposite: Herrenknecht's boxhole boring machine drives narrow link;

Above: In trials at Clara mine, Germany

Below: The copper mine at Northparkes



Rio Tinto and Copper processing

At Rio Tinto's Northparkes mine, in Australia, the volcanic geology holds copper-gold systems with some silver. The processing sequence at Northparkes involves crushed ore handling, grinding, flotation, concentrate thickening and filtration, concentrate handling and also tailings disposal.

After collection at the cone-shaped funnel, Northparkes eliminates "rehandling" by haulage from the intermediate ore pass to a gyratory crusher by, instead, feeding from a primary bin straight to a crusher installed underground. The crushed ore is then delivered by conveyor to two coarse stockpiles on the surface, each with a capacity of 150,000 tonnes. Below the stockpiles the material is processed through four vibrating feeders to reclaim the ore for the grinding mill, ball milling and then flash flotation.

The flotation modules are linked to grinding circuits, and aims to float a sulphide concentrate to recover the major copper and gold bearing minerals. The circuits consist of pre-float, scavenger, cleaner, cleaner-scavenger and re-cleaner treatment. The final concentrate produced for each module assays 34 per cent to 36 per cent copper and is pumped to a concentrate thickener. The final tailings from the modules are pumped to a tails thickener for dewatering.

The concentrate thickener takes the flow to an average underflow density of 60 per cent solids before being pumped into temporary storage tanks before filtration with ceramic discs, then discharged onto slow moving conveyor belts with weighing mechanisms. The concrentrate is temporarily stored prior to shipment to customers' smelters in Japan, predominantly, domestically and a few other countries.

Under its "Mine of the Future" initiative, Rio Tinto is pursuing improvements in mineral recovery systems in areas such as airrecovery/flotation, advanced leaching, sorting and lower energy use. Partners in these activities include Imperial College, London, on advanced mineral recovery, and University of Queensland, Brisbane, on advanced mineral sorting.

Rio Tinto's is seeking increased recovery of valuable minerals through programmes such as the eXDS (excite, detect and separate) technology platform, which includes the NuWave system under development to focus on copper.

R&D has seen steps include upgrading marginal ore or waste material, leveraging energy from earlier processing stages to reduce further consumption, and strategic partnerships with Norwegian firm Tomra and UK-based e2v. In recovering copper from waste streams, the company aims to boost throughput at the concentrator, delivering more tonnes per unit of capital investment. With a pilot plant built over 2010-11, scaling up is being explored with a further pilot at its Kennecott copper mine, in Utah.

Work is also underway to optimise the flotation process. When flotation bubbles are too heavily or under-loaded, there is poor performance – heavy loading sees froth flow too slowly and burst before overflow, whereas fast flow has bubbles bursting quickly, both resulting in low recovery. The reserarch is pursuing the optimum balance of froth stability against flow motion.

proposed 'Step Change' expansion of the existing block cave layout to create a greater, interlinked underground network to boost output and productivity. A 2010 study indicated that the expansion could see ore extraction from Northparkes reach 30 million tonne per year from multiple block caves. Future block cave zones to be tied by the tunnels include E26 Lift 3, E48 Lift 2, E22 and GRP314.

A USD 114M pre-feasibility study into the expansion plan included underground diamond core drilling to establish a fuller picture of the layout and boundaries of the mineralisation zones. In total, approximately 155km of core drilling was performed. Next, and just getting underway at Northparkes, are the in-field verification trials of the new Mobile Tunnel Miner (MTM) – a cross between a roadheader and TBM – developed by Aker Wirth in reference to Rio Tinto's "Mine of the Future" initiative, launched in 2008.

Rio Tinto said "mine design is our most important value creation," – and "protection lever", it added. The trials of the Aker Wirth MTM tunnel boring system have been integrated into the expansion studies at the mine.

Northparkes is one of seven main copper interests held wholly or through equity share by Rio Tinto. With many prospects to exploit through block cave mining, the company has set up the Rio Tinto Centre for Rapid Underground Construction, based at the Centre for Excellence in Mining Innovation in Ontario, Canada, for training and to build technical capability. Other underground mine expansions that will tap the resource include Kennecott in Utah and Oyu Tolgoi, in Mongolia. At Kennecott, the company is pushing underground with near term development of the North Rim Scarn zone which has both copper and gold.

Above, left: Access and exploratory tunnel at Los Bronces copper mine, Chile

Above, right: Ok Tedi copper and gold mine, in Papa New Guinea

Opposite: Robbins TBM currently at the Stillwater complex was used previously at Magma mine, in Arizona

Below: Block caving setup diagram

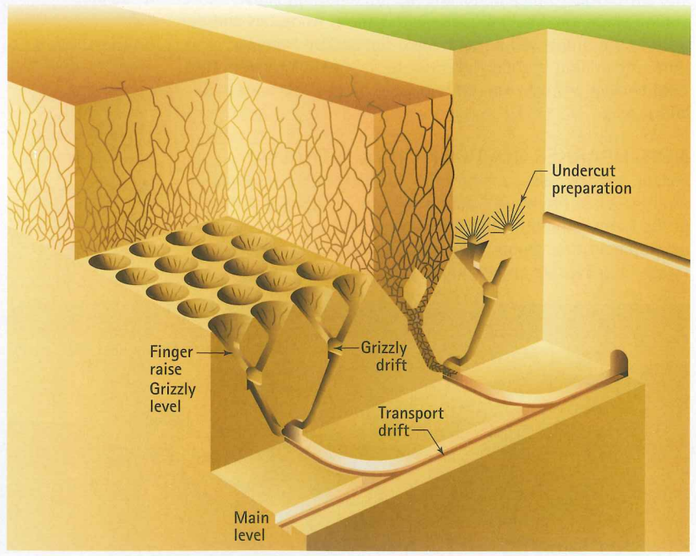
Pre-feasibility studies up to USD165M have been approved up to 2014 and it is anticpated that, following development tunnelling, first production could be in about six years.

Starting 2013, the Kennecott mine will also host the trials-in-the-field of the Atlas Copco Mobile Miner. Rio Tinto says the mobile miner is expected to allow more than 10m/day of tunnel construction, nearly twice the rate of conventional methods. Oyu Tolgoi – a "world class asset" – will see a switch from open pit to complete underground development in the transition from Phase 1 to Phase 2 of the mine.

Underground extensions are also seen for the massive Grasberg mining complex. However, it will be a variant on block caving – a 'panel cave mine' where the active mining area progressively migrates along a 'panel'.

Rio Tinto's Resolution mine is planned to be one of the major underground mines in the future even though the top of the mineral resource is about 1.5km below the surface with the production level at approximately 2km deep. The mine has copper ore with significant molybdenum.

John McGagh, head of innovation with Rio Tinto, says: "More mining is moving underground as deeper ore bodies are identified and open pits come to the end of their lives."



Diamond processing with Petra

Once mined, kimberlite ore is next crushed in the sequential quest to find and extract the diamonds. The processing steps takes the crushed ore though a series of screens, jigs and scrubbers but even then the diamonds are not obvious in the heavy material.

A combination of hi-tech and the most basic methods are the key steps to follow and pinpoint the diamons in the rough. The processing system employs X-rays and/or a grease table plus sorting by hand.

X-rays are used because most diamonds luminesce, allowing them to be sorted out of the heavy material. However, some don't respond too well to X-rays, such as the more valuable Type II stones. Processing then turns to exploit another natural quality of diamonds – their hydrophobic, or water repellant nature; the material is placed on a greased table and when the wet concentrate is washed off the diamond are found sticking to the grease

While the waste material is stored in tailings, some of which may hold economic grades of kimberlites and alluvial deposits missed by earlier processing methods, the stones go off to be sorted where they are categorised and value assigned by experts. The stones are sorted into parcels according to shape, size, clarity and colour, and this step in the prcessing also sees gem quality diamonds part ways with the other stones, or 'boart', that will be destined for industrial use.

The higher value stones will then be cut and polished, usually more than half the mass being removed in the process to arrive at the desired gem, where it is valued for colour, carat, clarity and cut.

PETRA DIAMONDS, SOUTH AFRICA

Block caving is also a key underground mining method for diamonds, such as at the Cullinan and Kimberley mines owned by Petra Diamonds in South Africa. The technique is also used at the company's Finsch mine where it is supplemented by sub-level caving, which uses smaller, intermediate-level excavations that last for shorter periods.

With their shorter livespans, the sub-level caving operations do not need the same degree of permanance in infrastructure support as required by block caving.

However, these jabs at the ore have slighly higher operating costs as they call for relatively more drill and blast excavation, the company notes. The advantage for Petra, therefore, at Finsch mine is the greater flexibility afforded to production, such as being a bridge for output while new areas are opened up. For example, ensuring production levels are maintained while the mine development effort is moving across to a new major ore block.

At Petra's Koffiefontein mine the front caving method is used, which saw an initiating excavation to the centre of the ore body and then the slot is opened up, or has an "overdraw" system used as the miners retreat out in stages.

Lower levels are also excavated with to function as the semi-permanent drawpoint, and these are developed ahead. Depending on the mine, the initiating slot may not be at the centre of the ore body but, instead, can be against the ore body boundary.

Elsewhere in the country – at the Helam, Sedibeng and Star mines – the company employs the complex 'fissure' or 'dyke' mining method where erosion has worn down kimberlite ore bodies to leave only the extremely narrow (less than 1m wide), magmatic vertical root zones.

The mining recovery is complicated by scale and geometry in the slender dykes but also due to variation in the types of kimberlite caused by magmatic intrusions at different spots over various periods of history.

Cullinan is one of the world's largest diamond mines and also a significant source of prized blue diamonds. Petra Diamonds bought into the mine, in Guateng province, in 2008 with a purchase from De Beers and quickly increased its stake by aquiring Al Rajhi's holding, and it now holds the controlling share. Mine began at the site 110 years ago but it wasn't until 1946 that mining switched from open pits to underground.

Mining at a depth of 747m currently, the mine plan is for 18 years and the potential life of the operations could last another 50 years, it estimates. The current expansion plan, to take annual production to 2.4Mcts (including 17 per cent from tailings processing, which is being stepped up) by FY2019 will see a new block cave mined once reached by mine development infrastructure in the western side of the orebody. Development and mining at this block could be boosted by new work on a major decline. Also on site, Petra has had shaft deepening work undertaken by contractor Murray & Roberts Cementation.

Comprising three neighbouring kimberlite pipe mines, the Kimberely complex has its origins in the late 19th Century and were amalgamated into De Beers in 1890. Petra Diamonds Ltd acquired its controlling (74 per cent) stake in 2010. The mine plan is for 10 years with potential life of a further 12 years from this mature asset, which is currently being mined at depths of 845m to almost 1km.

But in 2005 the mine had been closed by De Beers. However, working under the existing licence during a care and maintenance period from September 2007, Petra rehabilitated the deep underground mines and completion the purchase just over two years ago. The company is implementing a development plan that would double production from current levels to 135,000 carats annually by FY 2016

"Mine design is our most important value creation and protection lever"

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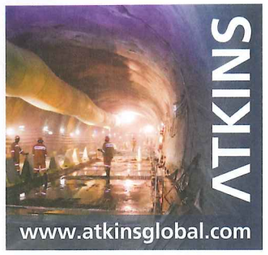

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BRITISH TUNNELLING SOCIETY

What's on

2013

Southern Railway Link Conference Koralm and Semmering tunnels
21 November 2013
Leoben, Austria
The Southern Railway SESSION is a forum to present experiences and discuss case studies to the above tunnels major projects and other projects along the Southern Railway.
www.suedbahntagung.at/index.php

Stuva Conference
27-29 November 2013
Stuttgart, Germany
The bi-annual conferency of the Stuva organisation heads to Stuttgart.
www.stuva.de/en

2014

Middle East Rail
4-5 February 2014
Dubai, UAE
With 82 exhibitors and attendance from nearly every regional rail operator in 2013, Middle East Rail conference and expo had more than 2,500 attendees. It's designed to help operators build and operate brand new rail infrastructure, as well as upgrading legacy networks. The event brings together rail developers, transport operators, government, contractors and suppliers to talk strategy, technology and innovation.
www.terrapinn.com/exhibition/middle-east-rail/

CONEXPO
4-8 March 2014
Las Vegas, USA
Held every three years, the exposition showcases the latest construction equipment, products, services and technologies. The show will be held at the Las Vegas convention centre.
www.conexpoconagg.com

Eurasia Rail
6-8 March 2014
Istanbul, Turkey
The Fourth International Rolling Stock, Infrastructure and Logistics Exposition features a tunnel construction section in 2014.
www.eurasiarail.eu

ISTSS
12-14 March 2014
Marseille, France
The Sixth International Symposium on Tunnel Safety and Security in Marseille, France will discuss current best practice and emerging demands and trends as well as research.
www.istss.se

World Urban Forum Seven
5-11 April 2014
Medellin, Colombia
The show for the UN-Habitat organisation. The United Nations Human Settlements Programme, UN-HABITAT, is the United Nations agency for human settlements. It is mandated by the UN General Assembly to promote socially and environmentally sustainable towns and cities with the goal of providing adequate shelter for all. This year the show visits Colombia.
www.unhabitat.org

Samoter
8-11 May 2014
Verona, Italy
This trade show dedicated to earth moving, site and construction machinery is held every three years. In 2011, the exhibition attracted 98,000 visitors and more than 900 exhibitors (of which almost 30 per cent were international).
www.samoter.it

World Tunnel Congress 2014
9-15 May 2014
Iguassu Falls, Brazil
Organised by the Brazilian Tunnelling Committee (CBT) of the ABMS (the Brazilian Association of Soil Mechanics and Geotechnical Engineering), as well as the International Tunnelling Association (ITA), and focusing on "Tunnels for Better Living", WTC 2014 will discuss and illustrate the importance of tunnels.
www.wtc2014.com.br

North American Tunneling Conference
22-25 June 2014
Los Angeles, California
The US Underground Construction Association (UCA)'s biennel tunnelling conferece takes place in Los Angeles, California in 2014.
www.smenet.org

InnoTrans
23-26 September 2014
Berlin, Germany
An international platform for buyers and sellers of passenger and freight transport technology, InnoTrans focuses on railway technology. The Tunnel Construction segment will be accompanied by International Tunnel Forum featuring a series of international discussions
www.innotrans.de

2015

World Tunnel Congress 2015
22-28 May 2015
Dubrovnik, Croatia
The jewel of the tunnelling calendar heads to the Dalmatian Coast for the technical event of 2015 as WTC returns to Europe. Many details are yet to be confirmed.
wtc2015.com

British Tunnelling Society

The BTS has a membership of almost 700 individual and 60 corporate members. It is one of the most vibrant gatherings of professional tunnellers in the world and traces its history back to its founding in 1971. Events are hosted at the Institution of Civil Engineers in London from 5.30pm every third Thursday of the month.

Port Mann Tunnel
23 November 2013
Contingencies for a high pressure EPB tunnel under a river, presented by Steve Skelhorn.

National grid cable tunnels
21 December 2013
A report on the project, which comprises 33km of 3m and 4m diameter tunnels across London. John Trounson, National Grid Stephen Meadowcroft, Costain will present an overview of the business case for the project and details of the progress made.

Concrete & Materials Engineering and its role in underground construction
16 January 2014
This presentation will explain the fundamentals use of concrete in underground construction and highlight the demanding requirements involved with building tunnel linings. The requirements of the Client, Designer and Contractor will be discussed and examples of concrete engineering and development on projects will be illustrated. Charles Allen, CA Consult, Martin Rimes, MVB JV, and Richard Sutherden, AECOM.

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